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TROUT AND SALMON CULTURE

(Hatchery Methods)

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TABLE OF CONTENTS

	Page
FOREWORD	7
ACKNOWLEDGMENTS	9
HATCHERY WATER SUPPLY	11
Chemical Characteristics	13
Dissolved Oxygen	13
Solubility of Oxygen	13
Hydrogen Ion Concentration (pH)	14
Carbon Dioxide	14
Alkalinity	16
Interrelationships of Carbon Dioxide, pH, and Alkalinity	16
Total Dissolved Solids	17
Effect of Galvanized Pipes on Hatchery Water Supply	17
Determination of Dissolved Oxygen	18
pH Determinations	20
STRUCTURE OF THE TROUT EGG	20
SPAWNING (EGG TAKING)	24
Spawn-Taking Facilities	24
Spawning Season	24
Effect of Temperature on Brood Stock and Eggs	27
Care of Brood Stock	27
Selective Breeding	28
Sorting Frequency	32
Size of Eggs	33
Anatomy of the Female Trout	33
Adhesiveness	35
Fertilization	35
Testing Fertilization	36
Dry Method	36
Effect of Broken Eggs in Fertilization	36
Salt Solution in Spawn Taking	36
Two-Man Spawning Method	37
Single-Handed Spawning Method	38
Incision Spawning Method (Salmon)	39
Effect of Light on Trout and Salmon Eggs and Alevins	43
MEASURING EGGS	44
California Volumetric Method	44
Burrows Displacement Method	47
Von Bayer Method	47
SHOCKING OR ADDLING EGGS	48
PICKING EGGS	49
Pipette Method	49
Siphon Egg-Picking Method	49
Salt Flotation Method	50
Flush Treatment to Eliminate Egg Picking	50
TROUT EGG BASKETS	51
FISH EGG INCUBATORS	54
Drip Incubator	54
Vertical Flow Incubator	56
PACKING EGGS FOR SHIPMENT	58
Green Eggs	58
Eyed Eggs	59
Shipping Eggs by Air	59
DEVELOPMENT OF TROUT AND SALMON EGGS	61
Temperature Units	64
HATCHERY TROUGHS	66
Trough Carrying Capacity	67

TABLE OF CONTENTS—Continued

	Page
TROUT AND SALMON PONDS	68
Rearing Pond Capacities	68
Circular Ponds	69
Raceway Ponds	69
AQUATIC VEGETATION IN PONDS	71
Photosynthesis	71
Aquatic Vegetation Control	71
TROUT AND SALMON NUTRITION	74
Fats	75
Minerals	76
Vitamins	77
Proteins	78
Carbohydrates	79
Interrelationships	79
FOOD STORAGE AND PREPARATION	80
HATCHERY DIET INGREDIENTS	84
FEEDING PRACTICES	88
Feeding Wet Feeds	90
Feeding Dry Feeds	93
GRADING FISH	101
Murray-Hume Automatic Grader	101
Morton Adjustable Grader	103
WEIGHING AND ENUMERATING FISH	104
Fingerlings—Scale Method	108
Subcatchables and Catchables—Scale Method	108
Scale Specifications	109
Displacement Method	109
LENGTH-WEIGHT RELATIONSHIP IN RAINBOW TROUT	110
Condition Factor	110
TRANSPORTATION OF TROUT AND SALMON	111
Effects of Metabolic Waste Products on Fish During Transportation	111
Sodium Amytal in Fish Transportation	112
Use of Antifoam Emulsion	112
TROUT AND SALMON DISEASES	113
Symptoms	113
Diseases and Parasites	114
External Bacterial Diseases	114
Columnaris	114
Bacterial Gill Disease	114
Peduncle Disease	115
Fin Rot	115
Internal Bacterial Diseases	116
Furunculosis	116
Ulcer Disease	116
Red-mouth Disease	117
Fish Tuberculosis	117
Kidney Disease	118
External Protozoan Diseases	118
<i>Trichodina</i> spp.	118
<i>Epistylis</i> spp.	118
<i>Chilodon</i> supp.	118
<i>Costia</i> spp.	118
<i>Ichthyophthirius multifiliis</i>	120
Miscellaneous External Parasites	120
Copepods	120
<i>Salmincola edwardsii</i>	120
<i>Lernaea carassii</i>	121
Parasitic Worm	122
<i>Gyrodactylus elegans</i>	122

TABLE OF CONTENTS—Continued

	Page
TROUT AND SALMON DISEASES (Continued)	
Miscellaneous External Parasites—Continued	
Fungus	122
<i>Saprolegnia parasitica</i>	122
Internal Protozoan Diseases	122
<i>Hexamitus salmonis</i>	122
<i>Cryptobia borreli</i>	124
<i>Ceratomyxa shasta</i>	125
Miscellaneous Internal Parasites	126
Parasitic Worm	126
<i>Sanguinicola davisii</i>	126
Fungus	127
<i>Dermocystidium salmonis</i>	127
Virus Diseases	128
<i>Pancreatic Necrosis</i>	128
METHODS OF TREATMENT	128
Dip Method	128
Bath Method (Prolonged Dip)	129
Flush Treatment	129
Disinfection	129
Drug and Feed Mixing	130
CHEMICALS AND THEIR USES	131
Salt	131
Copper Sulfate	131
Acetic Acid	131
Formaldehyde (Formalin)	132
Pyridylmercuric Acetate (PMA)	132
Calomel (Mercurous Chloride)	132
Carbarsone	132
Sulfamerazine	133
Sulfamerthiolate	133
Acriflavine	133
Malachite Green	133
ANESTHETICS AND THEIR USE	134
MS-222 (Tricaine Methane Sulfonate)	134
Methyl Pentynol	134
Quinaldine	137
NETS AND SEINES	137
Treatment of Nets	139
Dip Nets	139
THE CLASSIFICATION OF FISHES	142
REFERENCES	144
APPENDIX A. CONVERSION TABLES	149
APPENDIX B. GLOSSARY	155

FOREWORD

This volume has been prepared at the request of many of the Department's fish hatchery personnel. A hatchery treatise has long been needed to acquaint the beginning employee with the rudiments of fish culture, and also to act as a handy reference for those already experienced in the work. In addition, it should lead to greater uniformity in operations and to increased hatchery efficiency. It will also be helpful to the growing number of private trout hatchery operators.

Even though the art of trout culture dates back to the year 1741, when Stephen Ludwig Jacobi started artificial propagation in Germany, advances in methods and techniques were slow until shortly before World War II. During the past 10 or 12 years, applied science and mechanics have revolutionized fish hatchery operations. More advances have probably occurred during this period than since the very beginning of trout culture. The uses of new chemicals in treating diseases in hatcheries, eradicating undesirable fish populations, spawning, and transporting fish, and the employment of labor-saving devices such as fish loaders, self-graders, incubators, and dry feeds are only a few of the advances illustrating the progress made. They indicate that fish culture is at last beginning to receive the recognition and research that it deserves. With a greater demand for hatchery-reared fish each year, additional important advances are sure to take place.

In considering literature to be embodied in this volume and suggestions received from Department employees, attention was directed especially to subjects which would benefit the average hatcheryman and assist him with his everyday problems.

EARL LEITRITZ
May, 1959

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Trout and Salmon Culture

(Hatchery Methods)

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HATCHERY WATER SUPPLY

The characteristics of the watershed in which a hatchery is located, such as mineral content of rocks and soil, rainfall, hydraulic gradient, range of temperatures, and amount of foliage, control the primary characteristics of a hatchery water supply. Very heavy rainfall areas, headwater streams, and mountain locations with steep stream gradients are generally low and sometimes deficient in mineral content. Limestone areas supply calcium and magnesium, which are beneficial to growth and bone structure of fish. These waters also have a higher bicarbonate alkalinity, which tends to buffer and resist the effect of contaminating substances, such as acids or alkalis.

Moderately steep gradients above the intake are desirable for aeration; however, very steep and narrow canyons are most subject to flood damage. Good plant cover, such as trees, grass, and brush, is desirable because it minimizes erosion and silting of the hatchery water supply. Shade further tends to prevent the reflection of extremes of air temperature in changing water temperatures. A moderate and even temperature between 45 and 60 degrees F., depending on the objectives of the installation, is desirable.

Sluggish streams, swamps, bogs, springs, and wells are often deficient in dissolved oxygen, low in pH, and high in free carbon dioxide. These disadvantages can usually be remedied by proper aeration. Springs and wells ordinarily have the advantages of moderate and uniform temperatures and absence of diseases and pollution.

Any human activity on a watershed above the hatchery supply, such as dairying, stock raising, agricultural activity, summer resorts, lumbering or mining, increases the tendency towards silting, organic or inorganic pollution, and changing stream stages and temperatures, all of which are reflected in a less desirable water supply for hatchery purposes.

A common difficulty in well supplies is that they are apt to have an excess of gas. This is sometimes indicated by a milky appearance as the water enters the troughs or ponds. It may cause severe fish losses due to the formation of gas bubbles in the blood, under the skin, and in the eyes. Adequate aeration before use in the hatchery will overcome this difficulty.

An excessively high mineral content, as at Fillmore Hatchery in southern California, may prevent normal development of trout eggs. On the other hand, such water may produce outstandingly rapid growth of fish after they are hatched.



FIGURE 1. Fish Springs, Inyo County, California. A spring flowing approximately 20 c.f.s. of clear water at fairly constant temperature of 60 degrees F. provides this excellent hatchery water supply. In order to dissipate some harmful gases present and increase the oxygen content, a portion of the water used is treated by pumping it through the aerator in right center of picture. Photograph by Edwin P. Pister, April, 1956.

Recent agricultural and livestock publications show that livestock fed on green feeds grown in limestone deficient areas, with heavy rainfall, fail to develop properly. While the feed tonnage produced on such soils may be high, it lacks certain growth-producing qualities that cannot be detected by present chemical methods. Similarly, it is altogether possible that hatchery water supplies from like areas may have deficiencies which do not show up in chemical analysis.

From the above discussion, it is evident that many factors should be considered in selecting and installing a satisfactory water supply. Desirable features may be summarized as follows: (1) moderate rainfall, (2) moderate gradient, (3) good cover, such as trees, grass, and brush, (4) adequate limestone and other mineral deposits, (5) uniform and moderate temperature, (6) freedom from grazing, logging, mining, and similar activities on the watershed above the hatchery supply, (7) a submerged intake, (8) a covered pipeline to minimize temperature changes, (9) a moderate gradient from intake to hatchery, (10) adequate aeration, and (11) enclosure and covering of the water supply to prevent surface contamination. A water supply from suitable springs is more desirable than one from wells, streams, or lakes.

Chemical Characteristics

Dissolved Oxygen

M. M. Ellis et al. (1946), in their studies on favorable water environment for freshwater fishes, conducted some 5,800 oxygen determinations at about 1,000 stations throughout the country. The analyses for dissolved oxygen on 1,300 samples from waters with a good-sized fish fauna ranged from 4 to 12 p.p.m., but 84 percent of the good faunas were found where oxygen values ranged from 5 to 9. They stated that 3 p.p.m. is approximately the lethal point for freshwater fishes at summer temperatures but that respiratory difficulties developed below 5 p.p.m. The lowest safe level for trout is about 5 p.p.m. and 7 p.p.m. is preferable. One investigator referred to by Ellis states that 10 to 11 p.p.m. is best for trout and that they may show discomfort when dissolved oxygen is less than 7.8.

The importance of adequate dissolved oxygen for fish warrants the inclusion of basic data on this subject.

Solubility of Oxygen

Table 1 shows the solubility of oxygen in parts per million for fresh water in equilibrium with air of varying pressure as represented by altitude changes from sea level to 10,000 feet. The included temperatures from 40 to 75 degrees F. cover the range usually encountered in California streams and hatcheries, the data for the more common temperatures from 45 to 55 degrees F. being shown by intervals of 1 degree. *The marked decrease in content of dissolved oxygen with increasing temperature and altitude should be particularly observed.*

The saturation level for dissolved oxygen is less in sea water, being approximately 75 percent of that for the same temperature in fresh water. Intermediate salinities have oxygen saturations that lie almost on a straight-line curve between the limits of fresh water and sea water. Instructions for making dissolved oxygen determinations in fresh water are given near the end of this section.

TABLE 1

Dissolved Oxygen in Parts Per Million for Fresh Water, in Equilibrium With Air

Temperature in degrees F.	Elevation in feet										
	0	1,000	2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000
40.....	13.0	12.5	12.1	11.6	11.2	10.8	10.4	10.0	9.6	9.3	9.0
45.....	12.1	11.7	11.2	10.8	10.5	10.1	9.7	9.3	9.0	8.7	8.4
46.....	11.9	11.5	11.1	10.7	10.3	9.9	9.6	9.2	8.9	8.6	8.3
47.....	11.8	11.3	10.9	10.5	10.2	9.8	9.4	9.1	8.8	8.5	8.2
48.....	11.6	11.2	10.8	10.4	10.0	9.7	9.3	9.0	8.7	8.3	8.0
49.....	11.5	11.1	10.6	10.3	9.9	9.5	9.2	8.9	8.6	8.2	7.9
50.....	11.3	10.9	10.5	10.1	9.8	9.4	9.1	8.7	8.4	8.1	7.8
51.....	11.2	10.8	10.4	10.0	9.7	9.3	9.0	8.6	8.3	8.0	7.7
52.....	11.0	10.6	10.2	9.9	9.5	9.2	8.9	8.5	8.2	7.9	7.6
53.....	10.9	10.5	10.1	9.8	9.4	9.1	8.7	8.4	8.1	7.8	7.5
54.....	10.8	10.4	10.0	9.6	9.3	9.0	8.6	8.3	8.0	7.7	7.4
55.....	10.6	10.3	9.9	9.5	9.2	8.9	8.5	8.2	7.9	7.6	7.3
60.....	10.0	9.6	9.3	8.9	8.6	8.3	8.0	7.7	7.4	7.1	6.8
65.....	9.4	9.1	8.8	8.4	8.1	7.8	7.5	7.2	7.0	6.7	6.4
70.....	9.0	8.7	8.4	8.0	7.8	7.4	7.2	6.9	6.7	6.4	6.1
75.....	8.6	8.3	8.0	7.7	7.4	7.1	6.8	6.5	6.3	6.1	5.8

Hydrogen Ion Concentration (pH)

Because of its convenience, the pH scale¹ is quite widely used as a method of expressing hydrogen ion concentration; i.e., the acid or alkaline intensity of a water. On the pH scale, which ranges from 0 to 14, the neutral point is 7; lower values are more acidic and higher values more alkaline. The pH of natural waters will vary from about 4 to 9, the lower values being found in boggy or swampy areas, the higher ones in streams such as our western alkaline streams. Ellis et al., as the result of some 10,000 tests, state in their bulletin that normal values range from 6.7 to 8.6, and that in 90 percent of the areas where good freshwater fish faunas were found the pH range was 6.7 to 8.2. Values outside this range should be regarded with suspicion. Normally, the lower the pH value, the lower the mineral content. In general, waters slightly on the alkaline side support more fish than waters on the acid side. Instructions for making pH determinations will be found near the end of this section.

Carbon Dioxide

All natural waters contain some carbon dioxide, the quantity at equilibrium being approximately 2 p.p.m. In well supplies, carbon dioxide may be extremely high and is usually associated with a deficiency of dissolved oxygen. Low values of 1 p.p.m. or less usually indicate algal activity, which tends to absorb the free carbon dioxide, at the same time liberating dissolved oxygen. Low carbon dioxide is, therefore, usually associated with high oxygen values. Values above the normal of 2 p.p.m. may be looked upon with suspicion, since they may indicate either pollution from organic waste or a deficiency of oxygen.

¹ pH is the negative value of the power to which 10 is raised in order to obtain the concentration of hydrogen ions in gram-molecules per liter.



FIGURE 2. San Joaquin Hatchery, Fresno County, California. This hatchery is located below Friant Dam on the San Joaquin River and is operated on 25 c.f.s. of water received from Lake Millerton, a fluctuating reservoir behind the dam. This is an excellent example of a man-created hatchery water supply. To insure cool temperatures, water is drawn from a low level in the reservoir. This makes it necessary to treat the water by passing it through the aerating tower in left center of photo, which dissipates any harmful gases that may be present and adds sufficient oxygen to make the water safe for fish hatchery use. *Photograph by William M. Carah, May, 1956.*

Alkalinity

The alkalinity of normal fresh waters results principally from calcium and magnesium bicarbonates, and is sometimes associated with potassium or sodium bicarbonate. In very alkaline waters, carbonates as well as bicarbonates may be present. Hydroxide, the most caustic form of alkali, is not found in natural waters unless caused by pollution. Both hydroxides and carbonates show a red color with phenolphthalein, whereas bicarbonates do not. For this reason, phenolphthalein is used to test for the presence of hydroxides and carbonates, and methyl orange is used for bicarbonates. While alkalinity of normal fresh waters is due principally to bicarbonates, it has become general practice in reporting alkalinity to calculate it in terms of calcium carbonate. When the alkalinity is reported as methyl orange alkalinity, only bicarbonates are indicated, but the calculation is in terms of calcium carbonate.

The quantity of bicarbonates present in most California streams varies from a minimum of about 5 p.p.m. to about 200 p.p.m. The higher values, being associated with larger quantities of calcium and magnesium, are considered to be more beneficial to fish life, while streams of extremely low alkalinity may be deficient in certain mineral essentials. However, neither extremely low nor extremely high methyl orange alkalinity within the range previously stated may be considered detrimental to fish life. The determination of alkalinity is, therefore, usually for the purpose of classifying the water within a certain range or type rather than for determining whether a water can be classed as satisfactory or unsatisfactory.

Interrelationships of Carbon Dioxide, pH, and Alkalinity

A definite relationship exists between the above three water components. With a normal content of carbon dioxide, the pH increases as the alkalinity increases. Having determined the latter two, the carbon dioxide value can be computed or read from a chart without the necessity of making an analysis.

With a water that is high in carbon dioxide and, therefore, below normal pH (more acidic), aeration will cause a loss of carbon dioxide and a corresponding increase in pH (more alkaline). A simple test that may be of some value in hatcheries consists of the addition of a few drops of an indicator, such as Universal Indicator, to a small quantity of the hatchery water in a flask or bottle. The color produced is observed and then the water is agitated by thoroughly shaking the flask, to see if an appreciable color change occurs. A change in color toward the alkaline side indicates loss of carbon dioxide and the probability that the water is deficient in oxygen. A change in color toward the acid side indicates a decrease in pH, and the usual interpretation would be that the water supply is well aerated and that the carbon dioxide content is extremely low, due to photosynthetic action of aquatic plants.

The use of Universal Indicator at hatcheries for testing the water before and after aeration may be found very useful in indicating changes that occur in the characteristics of the water supply, and may at least give a clue to difficulties that develop.

If it is desired to express alkalinity in terms of bicarbonates rather than in the conventional manner as calcium carbonate, the latter figure should be multiplied by 1.22. In some reports the term "fixed carbon

dioxide" is used rather than alkalinity, and this term includes all of the carbon dioxide present as normal carbonates plus half of that present as bicarbonates. When a water contains only bicarbonates, as is normally the case, the alkalinity figure in terms of parts per million calcium carbonate can be converted to the equivalent quantity of fixed carbon dioxide in terms of cc. per liter by multiplying by the factor 0.18.

As previously stated, with normal carbon dioxide there is a fixed relationship between pH and alkalinity. Table 2 indicates, for varying pH values, the corresponding alkalinity when the carbon dioxide content is 2 p.p.m. Lower pH values than those in the table for given alkalinities represent either pollution or under-aeration, while higher pH values indicate good aeration and high activity of aquatic plants.

TABLE 2

Normal Alkalinities and pH Values When the Carbon Dioxide Content Is 2 p.p.m.

pH	Alkalinity in p.p.m.	pH	Alkalinity in p.p.m.
6.4	2.5	7.4	25.0
6.5	3.0	7.5	31.0
6.6	4.0	7.6	38.0
6.7	5.0	7.7	50.0
6.8	6.0	7.8	60.0
6.9	8.0	7.9	80.0
7.0	10.0	8.0	100.0
7.1	12.0	8.1	120.0
7.2	15.0	8.2	155.0
7.3	20.0	8.3	190.0

Total Dissolved Solids

The mineral content or total solids in parts per million for California streams varies between quite wide limits. The minimum content as shown in Water Supply Paper No. 237, titled "Quality of California Surface Waters", Van Winkle and Eaton (1910), is 8.1 p.p.m., and the maximum indicated is 1,766 p.p.m. The above paper is an excellent reference on characteristics of California surface waters. Present hatcheries within the State have mineral contents varying between the limits indicated above, the lowest being Mt. Whitney Hatchery with 57 p.p.m., and the highest, Fillmore Hatchery with 1,080 p.p.m.

Effect of Galvanized Pipes on Hatchery Water Supply

It has been demonstrated that very small quantities of zinc, copper, or lead are lethal to several varieties of fish. Zinc used in the galvanizing process will, under certain conditions, depending on the pH and temperature of the water, go into solution. Since the toxic effect of zinc in small quantities is cumulative, trout and salmon may be killed. Rainbow trout two to four weeks old have been killed in a water supply having a pH of 7.6 and containing 0.04 p.p.m. zinc.

Small concentrations of zinc in solution, resulting from water flowing through only 15 feet of 1½-inch diameter galvanized pipe at the rate of 30 gallons per minute, have been proven responsible for heavy losses among rainbow trout fry.

In selecting pipes, flumes, and conduits for hatchery use, galvanized material must always be avoided.

Determination of Dissolved Oxygen

A number of methods for the determination of dissolved oxygen are available. One of the most widely used is the azide modification of the Winkler method, which is described below. It should be borne in mind that size of sample, strength of reagent concentrations, and amounts of reagents used may be varied with different applications of this method.

When dissolved oxygen determinations are to be made in waters that are high in iron (ferric or ferrous), nitrites, organic matter, sulfides, sulfites, polythionates, hypochlorites, suspended matter, and other oxidizing and reducing substances, it may be necessary to select a modified method in order to prevent their influencing the test. For modifications of oxygen determinations, one should consult a reference such as "Standard Methods for the Examination of Water, Sewage, and Industrial Wastes" (American Public Health Association, 1955).

Keep all equipment clean. Do not mix medicine droppers or chemicals in reagent bottles. Label all reagent bottles with the name of the solution contained.

Caution: Both sulfuric acid and alkaline potassium iodide cause severe burns. Do not get in eyes, on skin or clothing. If you do, flush

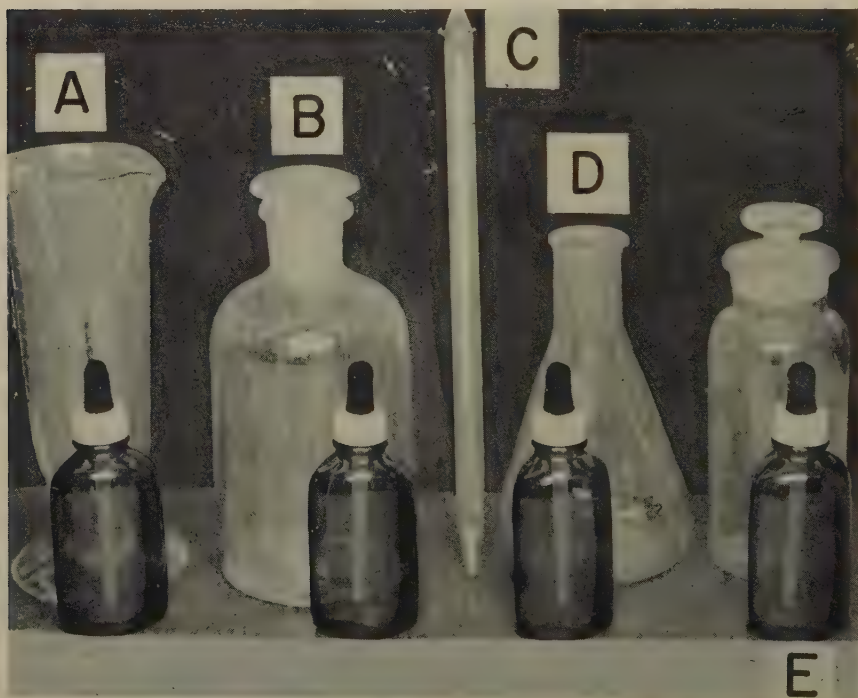


FIGURE 3. Equipment used in making O_2 determinations in the field. A, graduate; B, sample bottle; C, pipette; D, Erlenmeyer flask; E, reagent bottles. Photograph by Harold Wolf, September, 1958.

immediately with water. For affected eyes or severe burns, get medical attention.

Equipment required:

- Glass-stoppered sample bottle, 250 cc. capacity; at least one.
- Erlenmeyer flask, 300 to 500 cc. capacity; one.
- Graduate; one.
- Pipette, 10 cc. capacity calibrated in 0.1 cc. increments; one.
- Reagent bottles, two- or four-ounce capacity with screw-on medicine dropper top; four.

The following reagents are required in making dissolved oxygen (O_2) determinations when using the azide modification of the Winkler method.

1. Manganous sulfate ($MnSO_4$) solution.

Dissolve 480 grams of $MnSO_4 \cdot 4H_2O$ (or 400 grams $MnSO_4 \cdot 2H_2O$ or 364 grams $MnSO_4 \cdot H_2O$) in distilled water, filter, and dilute to 1 liter.

2. Alkaline-iodide sodium azide reagent.

Dissolve 500 grams NaOH (or 700 grams KOH) and 135 grams NaI (or 150 grams KI) in distilled water and dilute to 1 liter. Dissolve 10 grams of NaN_3 in 40 ml. distilled H_2O and add with constant stirring to 950 ml. of the above solution.

3. Sulfuric acid concentrated, approximately 36 N.

4. Starch solution.

Make an emulsion of 5 to 6 grams of potato, arrowroot, or soluble starch in a mortar or beaker with a small quantity of distilled water. Pour this emulsion into one liter of boiling water, allow to boil a few minutes, and settle overnight. Use the clear supernatant. This solution may be preserved with 1.25 grams of salicylic acid per liter or by the addition of a few drops of toluene.

5. Standard sodium thiosulfate solution 0.025N.

Prepare by dissolving 6.205 grams of $Na_2S_2O_3 \cdot 5H_2O$ in boiled and cooled distilled water and diluting to one liter.² This solution may be preserved by adding 5 ml. of chloroform or 0.4 grams NaOH per liter.

Proceed as follows: To the sample as collected in a 250 cc. bottle, add 2 cc. of manganous sulfate ($MnSO_4$), followed by 2 cc. of the alkaline-iodide solution. These reagents should be introduced with a medicine dropper or pipette well below the surface of the sample with special care, to avoid introducing air bubbles. Stopper the bottle and mix by inverting several times. Allow the sample to settle until there is an estimated 100 cc. of clear supernatant. Carefully remove the stopper and immediately add 2 cc. of the sulfuric acid by running it down the neck of the bottle, restopper, and mix by gentle inversion until solution is complete.

Pour 200 cc. of the sample into an Erlenmeyer flask and titrate with the sodium thiosulfate solution until the sample is a light straw color.

² Prewieghed sodium thiosulfate tablets, sealed in plastic, have recently been developed. Each time a dissolved oxygen determination is desired, a tablet is simply added to the proper amount of distilled water, thus insuring a fresh solution of the correct concentration. These tablets are available from Anachemia Chemicals, Ltd., Champlain, New York.

The sample should be shaken or agitated during the titration to prevent overrunning the end point of the titration. After the sample has reached the straw-colored stage, titration is stopped and 1 to 2 cc. of the starch solution added. This will cause the sample to turn a bluish color. Titration is then continued as above until the blue color has just disappeared. The total number of cc. sodium thiosulfate solution that it takes to make the sample colorless is equal to the parts per million of oxygen in the sample. If 8 cc. is used, then the water sample contains 8 p.p.m. dissolved oxygen.

pH Determinations

There are two kinds of methods for determining pH: (a) electro-metric and (b) colorimetric. When highly accurate determinations are required, the electric pH meters are a must. In other cases, the colorimetric method should be adequate.

One system of determining pH colorimetrically involves the use of indicator solutions. These solutions are added to the sample and a color change occurs. The sample is then compared with a series of color standards. The sample is matched to the standard and the pH of the matched standard is the pH of the sample.

Another even simpler method uses a roll of paper which has an indicator impregnated in it. A strip of the paper is torn from the roll, immersed in the sample, then removed and compared with paper color standards. When the test strip of paper is matched, the pH is read from the paper color standards.

This product is called pHydriion paper and is manufactured by the Micro Essential Laboratory, Brooklyn 10, New York. It is usually available from local laboratory or chemical supply houses. These papers are available in eight wide-range and 20 short-range types. In general, it is advisable to cover the range pH 5 to 9. Ranges above or below this are usually for special purposes.

STRUCTURE OF THE TROUT EGG

Which came first, the egg or the fish? Rather than debate this subject here, we will turn to the hatchery which does not produce its own eggs. Here the egg comes first.

While much has been learned and written regarding the taking and care of fish eggs, a great deal remains to be learned. In comparing the work at many hatcheries and egg-taking stations, it becomes apparent that there is a great lack of uniformity insofar as egg-taking operations are concerned. Every fish culturist knows that eggs are delicate and require constant and gentle care. Certain temperature limitations must be maintained, smothering must be guarded against, rough handling or shock must be avoided, and fungus (*Saprolegnia*) must be kept under control. It is no secret that eggs which turn white are dead, but what makes them turn white? In order to better understand this subject, we will review a few points pertaining to the general structure of the trout egg.

The shell of the trout egg is porous. The minute pores can be seen with a low-power compound microscope. The shell is also elastic and varies in strength and thickness among eggs from different varieties

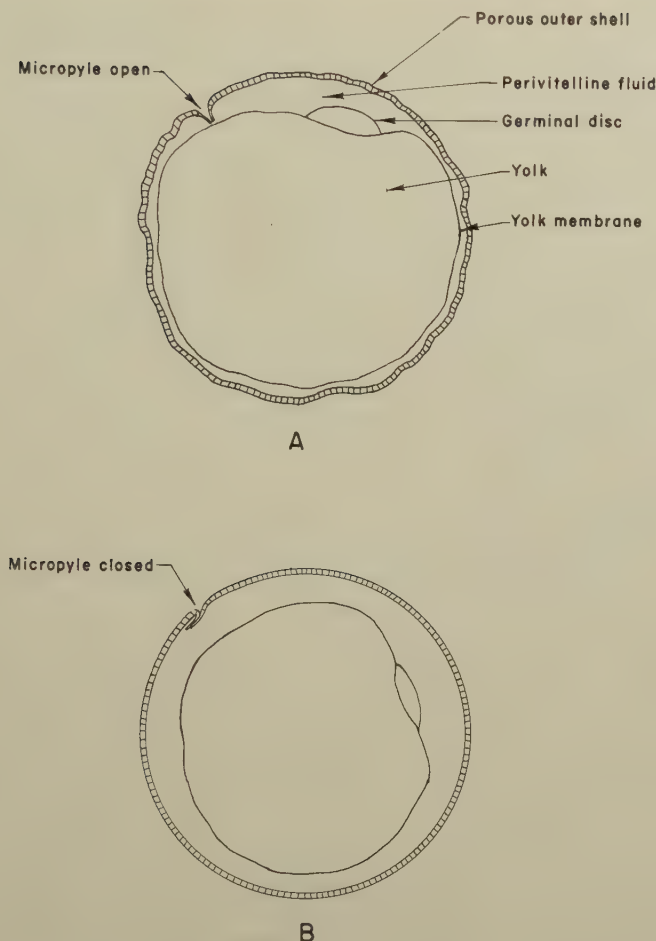


FIGURE 4. **A**, newly-taken trout egg, outer shell is not firm, egg feels soft and slightly adhesive; **B**, water-hardened trout egg, outer shell is drawn tight, micropyle is now closed, egg is firm and slick.

of fish and even from different females of the same variety. One cannot speak of water circulating through the shell, but there is no doubt whatever that it can diffuse through slowly. In general, the highly transparent shell, which allows a fairly good view of the developing fish, is thin. The thick shells are whitish and opaque. It is not known which type of shell is more desirable from the hatchery point of view, or whether the thickness can be influenced by diet. It appears to be an hereditary matter.

The shell contains one larger opening, the micropyle, through which the spermatozoon enters to fertilize the egg (Figure 4A). This opening was first seen in a trout egg by a German scientist named Bruch, in 1896. It is quite simple, consisting of a little hole at the base of a crater-like depression in the shell. The shell is not thinner around the hole than elsewhere, merely depressed. In response perhaps to some

chemical attraction from within the egg, the spermatozoon enters the micropyle and penetrates the yolk membrane to unite with the nucleus of the egg. It is a curious fact that although a number of spermatozoa may enter the micropyle, only one of them succeeds in uniting with the egg nucleus. Physiologists think this is due to a chemical phenomenon, and that the entrance of the spermatozoon into the micropyle is not the result of any chemical attraction but merely an accident that depends upon the presence of a very large number of spermatazoa. It might be mentioned that the mechanism of fertilization is a problem over which battles are still being fought by scientists.

The yolk membrane, mentioned above, is a protoplasmic layer which surrounds the yolk and holds it together. This membrane is very thin, comparable to that we see holding the yolk of a hen's egg together when we break one into a frying pan. It is not porous like the shell. The yolk membrane is of great importance to the fish culturist, for it is the rupture of this delicate layer which causes an egg to turn white and which is responsible for most of the losses which occur among eggs in hatcheries.

In a trout egg, as we see it in a hatching trough, there is a space between the yolk membrane and the shell and this space is filled with a fluid which embryologists call the perivitelline fluid. When an egg is freshly stripped from the female, there is no water in this space; in fact, the space itself hardly exists. The outer shell is quite limp, and the whole egg is rather collapsed, or flaccid. As the egg absorbs water it becomes swollen, and firm or turgid (Figure 4B). Eventually it absorbs 20 percent of its initial volume in water. This swelling is part of the "hardening" process familiar to all fish culturists. It was formerly thought that this absorption of water created a current through the micropyle which carried the spermatozoon into the egg. But we know now that this could hardly be a factor in the fertilization of the egg, for fertilization is effected within a few seconds after the spermatozoon and the egg meet, whereas water is absorbed over a period of 20 minutes or more, so that there could hardly be much of a current through the micropyle. Furthermore, high fertilization can be obtained by the dry method, in which no water is added until after the eggs and sperm have been mixed.

The reason why the egg absorbs water into the space between the shell and yolk membrane until it becomes turgid is explained as follows. When the egg is first placed in water a slight shrinkage of the yolk mass occurs as a result of the extrusion of a colloidal substance into the perivitelline space. This colloid has the property of taking up water, and upon so doing its volume is considerably augmented. The pores of the shell are so fine that although water and the class of soluble substances known as electrolytes can pass through, the colloids can not. Therefore, the colloids remain within the perivitelline space and continue to absorb water until their power to do so is counteracted by the resulting pressure of the shell. The stage of equilibrium is reached within about 20 minutes, and thereafter no further changes take place in the volume of the egg.

The outer shell itself toughens during the hardening period. This change is brought about through absorption of water into the material of the shell.

On the surface of the yolk, at the time the egg is ejected, is a quantity of protoplasm within which lies the egg nucleus. As the egg hardens, this protoplasm migrates toward one spot, where it gathers just beneath the yolk membrane into a small raised mass called the "germinal disc". This occurs whether the egg is fertilized or not, although the mass is never quite as high and compact in an unfertilized egg as in a fertilized one. It requires some hours after the hardening process is complete for the disc to reach its maximum height.

The yolk is a viscous, yellowish fluid which contains quite a number of oil droplets. These droplets congregate in the upper portion of the yolk and probably help maintain the germinal disc at the top of the egg. The whole yolk mass can rotate freely within the shell. If an egg is turned until the germinal disc is at the side, the yolk soon rotates and carries the disc back to the top of the egg. Therefore, the micropyle, although it must be located near the germinal disc in a newly-ejected egg, bears no relation whatever to the germinal disc once the egg is water hardened.

We are now ready to return to our original question of why a dead egg turns white. The yolk contains a good deal of protein material called globulin. The globulin is in solution in the yolk and is held in this state by the presence of salts. It cannot remain in solution in water which contains no salts or other electrolytes, so that removal of salts from the yolk causes it to precipitate. In a normal egg the yolk membranes prevent the salts from diffusing into the perivitelline space and from there through the porous shell. However, if the yolk membrane disintegrates or breaks and allows the salts to leak out, the globulin precipitates and turns white. Whiteness is caused by precipitated globulin.

If a white egg is placed in a weak solution of salt (about 1 percent), it will slowly regain its normal color. The globulin, because of the absorption of salt from the water, will again go into solution. If such eggs (kept in salt water) are examined under a binocular microscope, the cause of the whitening can usually be seen in the form of a break or hole in the yolk membrane. If the egg is replaced into fresh water, again the absorbed salt will leach out, the globulin will precipitate, and the egg will turn white.

An examination of the cleared egg will also disclose whether the egg was sterile or whether it had undergone some development prior to the rupture. Both kinds will be found among white eggs.

During the development of the embryo in the fertilized egg, the yolk membrane soon becomes covered by a much thicker wall of cells, so that after a while it is no longer in any danger of being broken. Until this occurs the egg is still tender. Naturally, a sterile egg never passes out of the tender stage. The familiar hatchery practice of agitating the eggs after they are eyed, called shocking or addling, ruptures the yolk membranes of the ever-tender sterile eggs. The result is a precipitation of the globulin and a whitening of the egg.

Little is known regarding the conditions which cause yolk membranes to rupture. Mechanical shock can rupture the membranes very easily. Every fish culturist is also familiar with the fact that when a white egg becomes fungused, and is not removed from the tray, the fungus gradually envelopes the neighboring live eggs and after a while

they also turn white. The fungus probably makes a chemical attack upon the membrane. No doubt chemical injury to the yolk membrane could also occur in certain polluted waters.

SPAWNING (EGG TAKING)

The act of obtaining eggs from female fish and sperm from male fish is referred to as spawning, egg taking, or stripping. The words egg and ova are synonymous. Even though the merits of artificial propagation are not as great as first claimed in the early annals of fish culture, the efficiency of artificial fertilization can hardly be disputed and fertilization of nearly 100 percent has been attained in trout eggs by artificial methods.

Spawn-Taking Facilities

It may safely be said that the less the fish are handled the better, and streamlining spawn-taking operations to reduce handling is certainly a step in the right direction. The modern spawning house is arranged so the fish are not carried into the spawning house, but instead are herded into the spawning enclosure without being taken from the water (Figures 5 and 6). For sorting and spawning purposes, the fish are dipped up a few at a time, and when spawned out are returned to the brood pond with a minimum of handling.

Maintenance of the inside of the spawning house at a comfortable temperature (about 70 degrees) greatly facilitates the spawning operation. One can understand that unless a person's hands are kept reasonably warm, it is difficult to know how much pressure is being applied to the fish in expressing the eggs. The egg taking operation is greatly speeded up under comfortable conditions, resulting in time saved, better fertilization, less injury to the fish, and a happy crew.

Spawning Season

The spawning season of trout varies to some extent with the locality and the temperature of the water. By nature, eastern brook and brown trout are fall spawners, while rainbows spawn in the spring (a complete list of the common and scientific names of the salmons and trouts of California is contained in the section *The Classification of Fishes*). In some California streams with runs of anadromous fishes, such as the Trinity River, there is hardly a month in the year when some strain of fish is not spawning. As an example, spring-spawning king salmon arrive in the upper river section at Lewiston the latter part of June. They are then followed by the summer and fall runs, which extend the salmon spawning season to mid-November. The king salmon runs overlap the silver salmon runs, which extend from November through January. The silvers in turn overlap the steelhead, which spawn during the period January through June. Actually, the steelhead of the Trinity River may be divided into those of the spring run (fish in general entering and migrating upstream on dropping stream levels while quite green, and spawning in the following season), and those of the fall run (fish in general entering on rising stream levels with sexual products in various stages of development, but spawning within the same season).

There are several ways in which the spawning season can be advanced. These include selective breeding, use of artificially controlled



FIGURE 5. Modern brood pond and spawning house installation at Mt. Shasta Hatchery, Siskiyou County, California. Design permits fish to be moved into spawning house without taking them from the water. *Photograph by George Farnham, February, 1958.*



FIGURE 6. Doors to spawning house move up, permitting the fish to be pushed inside the building for sorting and spawning. Note perforated aluminum grates used as crowding racks in moving fish. *Photograph by George Farnham, February, 1958.*

light, and injection of pituitary hormones. Selective breeding has been highly effective, and through this process the fall-spawning rainbow commonly referred to as the Hot Creek strain has been developed. Even though selective breeding is a very slow process, the results not being evident until several generations of offspring have been dealt with, the results are permanent and once the strain of fish has been developed it can be perpetuated by proper selection. It has been clearly demonstrated that the spawning time of trout can be advanced by the injection of pituitary hormones; however, this method is still in its infancy and, before the average hatcheryman will be benefited by its use, much needs to be learned regarding it. It offers interesting possibilities for crossbreeding varieties which spawn at different times of the year.

Effect of Temperature on Brood Stock and Eggs

Probably no other single thing regulates the development of eggs and growth of fish as much as temperature. It has been shown that rainbow trout reared in water held fairly constant at 60 degrees F. grow in length at the rate of about one inch per month. At 45 degrees F. they grow at less than one-quarter inch per month.

It is quite generally agreed that yearling and adult rainbow can withstand temperatures up to 78 degrees F. for short periods of time without harmful effect. It has also been shown that in order to produce eggs of good quality, rainbow spawners must be held at water temperatures not exceeding 56 degrees F., and preferably not above 54 degrees F., for a period of at least six months before spawning.

In order to get rainbow brood stock to grow rapidly and spawn when two years old, it is common practice to rear them the first 16 months of their life at a location where water temperatures are fairly constant at 60 degrees F., and then to transfer them to a location with a water temperature below 54 degrees F. to mature.

Just as water temperatures which are too warm (higher than 56 degrees) adversely affect egg development in rainbow and king salmon spawners, so do water temperatures which are too cold (42 degrees or lower) affect the development and incubation of trout and salmon eggs. In one experiment in which mature adult king salmon females, nearly ready to spawn, were placed in water ranging from 34 to 38 degrees, none of the females ripened and all died before spawning.

In an attempt to incubate king salmon eggs at a constant 35-degree temperature, mortality was practically 100 percent. Eggs held at water temperatures of 42.5 degrees or higher developed with only normal loss. Salmon eggs which had been held in water slightly above 42 degrees for a period of six days or longer could then tolerate colder temperatures without excessive mortalities. It is safe to say that the eggs of rainbow trout and king salmon will not develop normally in the fish if constant water temperatures above 56 degrees F. are encountered. It also follows that both rainbow trout and king salmon eggs cannot be incubated in water below 42 degrees F. without excessive loss.

Care of Brood Stock

As in all animals, the time of sexual maturity is one of the most critical during the life of a fish, so brood fish should be handled with the utmost care.

In order to obtain eggs of the highest quality, brood fish must receive an adequate diet. As more of the secrets of trout nutrition are learned, better diets and improved egg quality may be expected. Fish culturists are cautioned against using any diet containing regular cottonseed meal for brood fish. If fed in more than slight amounts, it will adversely affect egg production in fish, just as it affects the reproductive system in other animals. Apparently the effect of degossypolized cottonseed meal on the quality of trout eggs is unknown.

A female trout, heavily laden with eggs, cannot withstand the rough handling sometimes associated with poor hatchery practices. Great care should be taken during the sorting and spawning operation to dip up only two or three fish at a time. *Never make a pass through a pen of nearly mature females and fill the bag of the dip net with fish.* This can result in broken eggs, poor fertilization, and possibly permanent injury to the fish's reproductive system.

Selective Breeding

Improvement of animal and plant life of various types through selective breeding is an old art, which has produced nearly all of our domestic animals and cultivated plants. In many cases the evolution of our present strains and varieties is almost lost in antiquity. In recent years, the new science of genetics, applied to plant and animal breeding, has greatly accelerated the rate at which improvement can be made. Improved strains of hybrid corn, for example, have been developed rapidly.

In countries where fish farming is important, special strains have been developed for various purposes, including rapid growth, disease resistance, greater beauty, etc. There is no question that nature exercises selection in the survival of animals in various wild environments.

To meet the demands of an artificial operation, such as our present hatchery program, there are many things which must be considered to make the program a success. Production of eggs at the right time of year, so the resulting fish will reach correct size for stocking when they are needed, is highly important. The development of strains which mature at two years of age, instead of three, saves the cost of holding brood fish an extra year. Selection for large eggs gives the resulting fry a better start in life and higher survival.

The selection of females producing a large number of eggs is important, since it reduces the number of brood fish required. It is always important to select eggs of high quality. It is important to select the largest fish from a two-year-old strain, since this will insure a rapidly growing fish which will increase the economy of the production program. It is essential to select fish with good conformation and coloration in both the male and the female; otherwise, deformities and poorly-shaped fish will be produced. Disease resistance also can be developed through selective breeding.

The production of hybrid trout, through crossbreeding of different species, holds some promise but much more information is needed before it can be properly evaluated.

In California, selective breeding has been carried on to some extent since 1938. Selection has been limited almost entirely to rainbow trout,

of which two strains are propagated, spring-spawning and fall-spawning. It is of interest to note that the fall-spawning rainbow were developed over a period of many years, beginning about 1883, when eggs were taken from wild spring-spawning rainbow from the McCloud River, California, by the U. S. Fish Commission and shipped to its hatchery in Neosho, Missouri. After many years of selection at Neosho, some of the fish were shipped to its hatchery at Springville, Utah, where further selection for early spawning was made. As a result of continuous selection, these normally spring-spawning rainbow became fall spawners. A shipment of eggs of these fall-spawning fish obtained for Hot Creek Hatchery in 1933 formed the nucleus of our present stock.

The general procedure used in selective breeding is as follows: The date when the selection should be made is determined by the period when eggs are desired to fit into the hatchery production program. In general practice, the females are selected from two-year-old fish because there is more certainty of selecting rapidly-growing fish and individuals with good conformity. After the males and females have been selected, they are spawned. The eggs from each female are kept separate (Figure 7). These individual lots of eggs are measured and counted and kept in separate trays or compartments of trays in the hatchery. Each lot receives an identification number. A record of losses is maintained throughout the incubation period.

It is of interest to note that the losses in some lots are as high as 50 and 100 percent, suggesting that poor eggs encountered in production spawnings may come from a very few females.

Before the eggs hatch, it is customary to eliminate all lots that are not of exceptional quality. The remaining lots are then hatched in separate compartments in hatchery troughs. The losses of the fry for the individual lots are recorded as the fish develop.

When the fish reach approximately 50 per ounce they are carefully examined for deformities. At this time the records are carefully analyzed and a selection is made, based on the appearance of the fingerlings making good growth, the largest parent fish, the largest eggs, and the highest percentage survival in each lot.

The selected groups are then held until the fingerlings reach a weight of about five per ounce, at which time they are graded and the largest fish selected. All fish selected are then marked by clipping off certain fins. It is important to mark all fish held for brood stock to prevent any errors in the selective breeding program through unintentional mixing of the stocks in the hatchery.

When selecting for disease resistance, it is preferable to select the desirable fish at two years of age and mark them so they can be recognized after they have been exposed to and have survived disease epidemics for three or four years.

Generally the offspring of any single selection will spawn over a period of approximately three months, with about half spawning earlier than the selection date and half following the selection date. This division is not true when the selection is made earlier or later in the spawning period. Selective breeding must take place over several generations to advance or delay an established spawning period.



FIGURE 7. Eggs from select brood females are placed in individual hatching trays for observation and final selection. Photograph by George Bruley, December, 1958.

Through selective breeding of the Hot Creek strain of rainbow trout, two-year-old spawners have been developed in three generations. The number of fish spawning at two years of age has been increased from 53 percent to 98 percent. The egg production from two-year-old females has been increased fourfold in six generations. Weight of the selected fish at one year of age has increased from 5 ounces each to 10.2 ounces in five generations.

Selective breeding has developed strains of rainbow trout which spawn in all months of the year except May or June. Through continued selective breeding, it will be possible in the future to produce eggs in all months of the year in the amounts required for a year-round hatchery program.



FIGURE 8. Sorting brood fish for ripeness. Sorting trough is waist-high. Fish are dipped into trough a few at a time. *Photograph by J. H. Wales, February, 1958.*

Sorting Frequency

The interval at which brood females should be sorted during the spawning season varies among hatcheries, and depends to a large extent on water temperature and season. Normally, it is not necessary to sort the females as often early in the season as during the peak of the operation. To produce eggs of the best quality, it is necessary to watch the brood stock closely. The correct degree of ripeness must be attained in the females. Taking eggs before they are fully mature (ripe) is as bad as not sorting frequently enough, which may allow some of the females to overripen. Under the unnatural conditions associated with domestication, fish rarely deposit their eggs of their own accord. If they are not sorted often enough, overripe eggs are sure to be found. Such eggs are hard and glassy, probably as a result of contact with a serous ovarian exudation present in the fish, and are sometimes referred to as "moon-eyes". Besides being infertile, they may injure or even kill the fish.

Research has shown that the ripening of trout eggs can be represented graphically as a curve with a sharp apex. The peak of this curve represents the time of optimum fertility of a particular lot of eggs, which must be stripped at that time. If taken prior to this date, lower fertility results, due to the eggs not being completely ripe. If taken later, on the down side of the curve, overripe eggs are encountered.

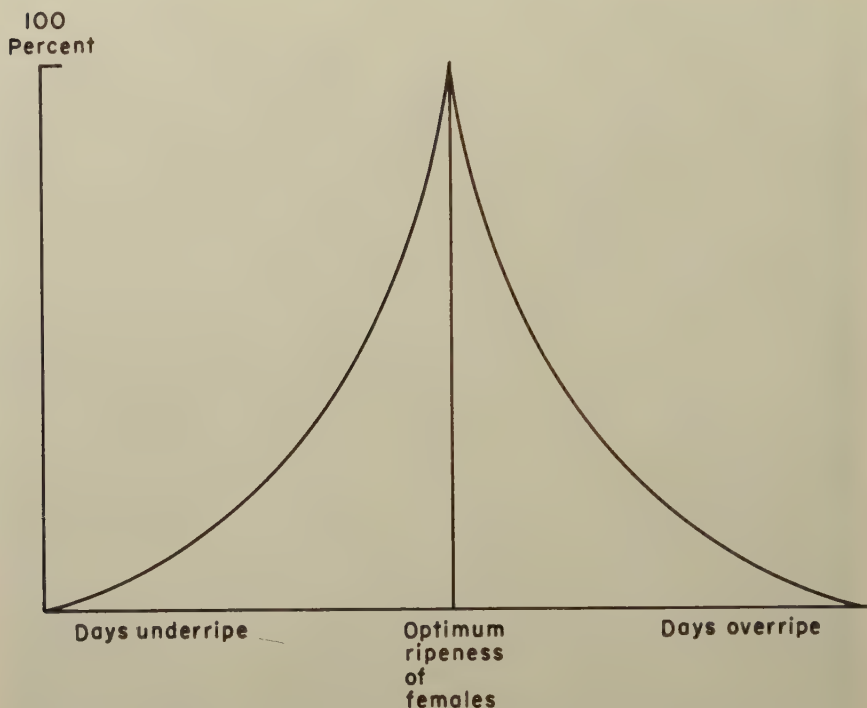


FIGURE 9. Effect of female ripeness on fertilization of hatchery trout eggs.

Correct timing, through proper and frequent sorting, is one of the greatest secrets of successful egg taking.

Size of Eggs

In general, the size of the egg depends upon the size and age of the parent fish, the larger specimens producing more and larger eggs. Egg size also varies among different strains of domestic brood stock, and among wild fish in different waters. It is reasonable to assume that competition among fry gives the larger fry a better chance for survival and faster growth. Hence, in selecting brood stock there is some advantage in selecting for larger eggs. Size, however, can be attained only at the expense of number. There is, therefore, some point at which, on the average, the forces favoring size are balanced by those favoring number. As a result of selective breeding, the eggs from domesticated stock are usually larger than those from wild fish. Mt. Whitney Hatchery spring-spawning rainbow brood stock average 427 eggs per ounce and a female produces 3.9 ounces or about 1,553 eggs when two years old. The same fish at three years of age produces about 9 ounces of eggs, averaging 254 per ounce or 2,210 eggs. This indicates that the size of the eggs increases by 40 percent between the second and third year of the female's life and the number of eggs produced increases by 42 percent, as shown in Table 3. This further points up the necessity of proper diet and handling of brood stock to insure their productive capacity over a period of several years.

TABLE 3
Record of Trout and Salmon Eggs Taken at California Stations

Variety	Location	Age	Number females spawned	Number eggs per ounce			Number ounces per fish	Number eggs per fish
				Small-est	Larg-est	Aver-age		
Rainbow, spring spawn.	Mt. Whitney Hatchery	Domestic, 2 years	2,570	540	350	427	3.9	1,553
Rainbow, spring spawn.	Mt. Whitney Hatchery	Domestic, 3 years	2,805	311	207	254	9.0	2,210
Rainbow, fall spawn.	Hot Creek Hatchery	Select, 2 years	30	490	420	447	5.78	2,600
Brown-----	Mt. Whitney Hatchery	Domestic, 2 to 4 years	618	290	225	249	5.65	1,751
Golden-----	Cottonwood Lakes	Wild	1,360	410	370	393	1.0	382
Steelhead-----	Snow Mountain Station, Eel River	Wild	461	240	200	221	18.75	4,304
King salmon-----	Fall Creek Station, Klamath River	Wild	489	80	73	76	38.53	2,902

Anatomy of the Female Trout

Before going deeply into artificial spawning, let us look at the anatomy of the female trout (Figure 10).

Some knowledge of the anatomy of the reproductive system will guide the spawntaker and provide a scientific basis for the job. Mature male and female trout have glands called gonads on each side of and above the digestive organs. The male has testes which produce individual spermatozoa, and the female has ovaries which produce eggs. Trout lend themselves better than most fish to artificial reproduction because the eggs are loosely held in a thin membrane and can easily be manipulated along the oviduct leading to the vent. However, eggs may be forced into the body cavity by awkward or careless practices. Such eggs can never be extruded and are eventually absorbed by the tissues.

Eggs, when taken, are only slightly adhesive and on extrusion and absorption of water become firm and slick.

If a fully mature (ripe) female trout or salmon is held by the tail, head down, the mass of eggs sags visibly toward the head and free eggs may settle into the forward end of the abdominal cavity outside the ova-containing membrane. The danger of this happening is even greater after the stripping process has begun and the tense condition of the supporting abdominal wall is relaxed. *Avoid holding a ripe female by the tail, head down.*

Forceful pressure in stripping may rupture the membranes and injure the ovaries, making the eggs sterile. Inasmuch as trout, in the state of nature, do not emit all of their eggs at one time, no forcible attempt should be made to expel more eggs than those which flow easily under gentle pressure. It may take several manipulations to obtain the eggs. Since the eggs in the posterior part of the ovary, i.e., those nearest the vent, are the first to ripen, it is not necessary to

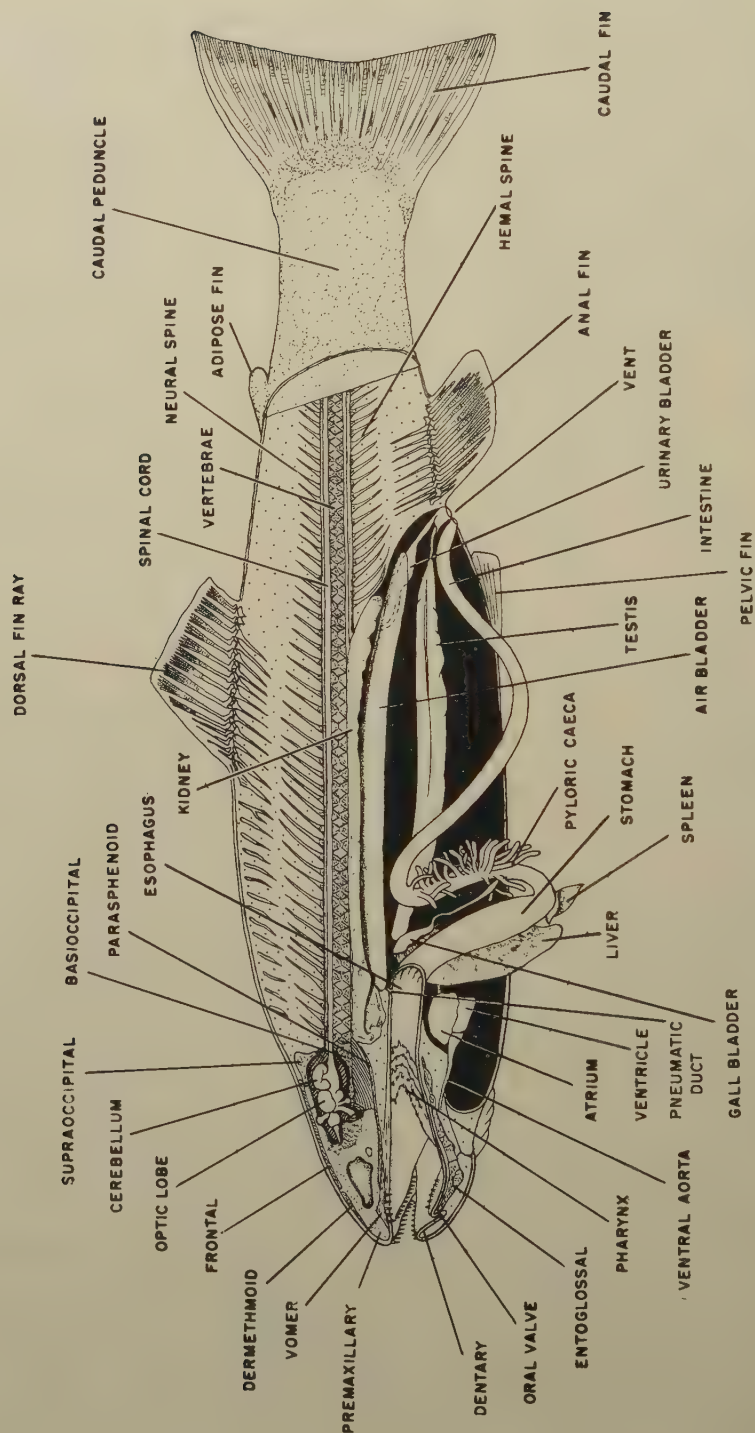


FIGURE 10. Anatomy of a trout.

apply pressure the whole length of the abdomen. Ripe female trout should be held tail down with the head high. This permits the eggs to flow or roll along the oviduct toward the vent.

Adhesiveness

Newly-taken trout eggs are slightly adhesive and this condition continues until they are water-hardened. It is due to the water filtering through the outer shell and not to any sticky substance on the egg. It may be compared to a depressed tennis ball which has been punctured. If one holds his thumb over the puncture during the time air is attempting to fill the ball, the latter will have a tendency to cling to one's thumb. It is understandable that an egg with many punctures (porous shell) would be adhesive during the filling or water-hardening process. As soon as the water-hardening process is complete, trout eggs are no longer adhesive.

Fertilization

The micropyle (Figure 4A), in its normal position in a newly-spawned egg, has the appearance of a small appendage resembling a minute cornucopia situated approximately at right angle to the outer shell and projecting inwardly. This small appendage commences to move to one side as soon as water entering through the pores starts mixing with the perivitelline fluid and fills the void between the outer shell and the yolk membrane. The micropyle is in its greatest open position at the time the egg is taken from the fish. As soon as it begins to move to one side, the opening decreases in size and continues to do so until the micropyle has moved into a position which completely seals off the opening to the outer shell. For this reason, the greatest chance for fertilization occurs immediately after the egg is taken. One can understand that the possibility of fertilizing the egg gets progressively poorer as the micropyle opening gets smaller, and since the spermatozoon enters only through the micropyle, fertilization is impossible after sufficient time has elapsed to allow the micropyle to close.

The matter of whether the eggs or milt should be taken first is usually left to the individual. However, usually the female is spawned first, then the milt is added, and the eggs in the pan are stirred gently. If no broken eggs appear, another female is spawned into the pan and then another male. By using a different male each time, the chance of fertilization being upset by use of an impotent male is greatly reduced.

The number of eggs produced by females of the same age and strain varies considerably. The amount of sperm extruded from a male varies from a few drops to a teaspoonful. It has been stated that one drop of sperm will contain enough spermatozoa to fertilize 10,000 eggs. It is, of course, necessary for contact between sperm and eggs to occur; hence, the necessity of stirring the eggs and sperm together.

Since there is a definite limit to the time that both the eggs and sperm remain viable, correct timing in the spawn-taking operation is important. The length of time either eggs or sperm remain active varies considerably and depends, perhaps, on several factors. Certainly, variety of fish and temperature are contributing factors. It is quite generally accepted that, in trout, both eggs and sperm lose their viability completely after about three minutes.

In taking trout eggs, it is best to use a dark or black spawning pan, so it will be easier to see the milt in the pan. Should eggs be broken, the white albumen from the broken eggs is also more easily detected in a black pan. Any pan of suitable size can be darkened by painting the inside with asphaltum varnish.

Testing Fertilization

As early as 1902, glacial acetic acid was used to aid in determining whether salmon ova had been fertilized (Rutter, 1902). He noted that the embryos in eggs 24 hours or older, when placed in a 5- to 10-percent acetic acid solution, turned white within a few minutes. The dead ova are cleared by the acid, so that the stage of development at which the ova died may be determined. The further the embryo has developed, the easier it is to make a determination. In making this test for the first time, it is best to make a comparative test with unfertilized ova that have been kept in water during the same period. By noting the number of infertile ova in a sample, it is not difficult to determine, within reasonable limits, the percentage of fertilization in a lot of eggs.

Dry Method

The old subject of dry method versus wet method is still being debated and apparently both methods are equally successful, depending to a great extent on the individual spawntaker. Advocates of the dry method claim that the micropyle remains open longer, and they explain it in this way: water entering the egg through the pores and mixing with the perivitelline fluid causes the micropyle to close. In the dry method, the process is supposed to be delayed. With the micropyle remaining open longer, more time can be taken in adding the sperm, and the eggs from several females can be taken in the same pan. An experienced spawntaker who selects his fish carefully, making sure that both males and females are ripe, seldom is rushed for time, and unless broken eggs (albumen) enter the pan, he is able to spawn several females, just as when using the dry method.

Actually, it is difficult to take eggs without getting some water in the pan, because some will usually drip from the fish and the holder's glove.

Effect of Broken Eggs in Fertilization

When eggs are broken in the spawn-taking operation, the process of fertilization is greatly hampered and at times completely stopped. Broken eggs in the spawning pan will appear as a white, creamy substance somewhat resembling sperm. This is actually the albumen from the broken eggs and, unless it is washed off immediately, some of it will lodge over the micropyles and prevent the spermatozoa from entering. Broken eggs probably contribute as much to poor fertilization as does any other factor. When albumen appears in the spawning pan, it should be washed off immediately, the sperm added, and the pan emptied of eggs before more are added.

Salt Solution in Spawn Taking

It has been demonstrated that when eggs are taken by inexperienced spawntakers or when eggs are extremely soft-shelled, with many broken eggs resulting, fertilization can be improved by the

use of a salt solution. A sufficient amount of the solution is added to the empty pan to fully cover the number of eggs to be taken, regardless of whether eggs from one or more females are taken. The salt solution holds the albumen from the broken eggs in solution and keeps the micropyles from becoming clogged. It also prevents agglutination of the sperm. An experienced spawntaker normally uses a salt solution only when eggs are soft and an excessive number of eggs are broken in stripping them from the fish. Various salt solutions have been developed and considerable latitude is allowable in their composition and application. Two salt solutions which have proven satisfactory for egg-taking purposes in California hatcheries can be prepared as follows: (1) dissolve one ounce of common table salt in one gallon of water, or (2) dissolve $3\frac{1}{2}$ fluid ounces of 96 cc. common table salt in 10 quarts of water.

Two-Man Spawning Method

In taking trout eggs either the single-handed or the two-man method is used, and the choice of method is usually left to the man in charge of the hatchery. In California, the two-man method is generally used.

In the two-man method (Figure 11), one man holds the fish and the other spawns. The holder wears gloves on both hands and grasps the fish, male or female alike, by the caudal peduncle with the right



FIGURE 11. Artificially spawning a female trout by the two-handed method. Photograph by J. H. Wales, January, 1959.

hand and by the pectoral fins with the left hand. The egg pan is placed against a padded block on the spawning bench and the holder moves the fish over the spawning pan with his right hand resting on the padded block. The spawning pan is usually slightly recessed into the spawning bench, to prevent it from being knocked off the bench in the event a fish should struggle.

With the fish held tail down, so the ripe eggs will flow naturally toward the vent, the spawntaker, who stands on the opposite side of the bench, gently presses out the eggs with the thumb and forefinger, beginning pressure just forward of the vent. The hand is then moved forward toward the head of the fish and further gentle pressure is applied as necessary to assist the natural flow of eggs, until all that will come freely from the fish are obtained. Pressure should never be applied forward of the ventral fins, since even slight pressure applied over the heart and liver may injure the fish.

Do not attempt to strip the female entirely clean of eggs. The reason for this is obvious to those who have taken spawn, for it is in extracting the last hundred or so eggs that one is most apt to break shells and force from the fish eggs which may not have fully matured.

Single-Handed Spawning Method

In the single-handed method, the spawner both holds and spawns the fish. The procedure is as follows: Assuming the spawner is a right-

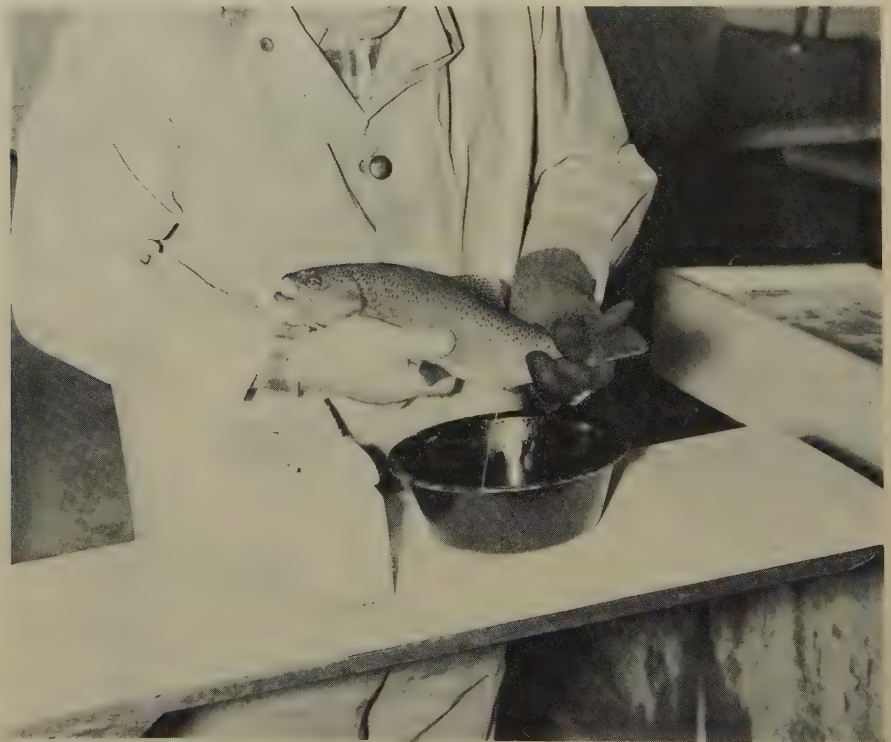


FIGURE 12. Taking sperm from a male trout by the single-handed method. Photograph by J. H. Wales, January, 1959.

handed person, he wears a glove on his right hand, and the left hand is left bare. A ripe female is grasped by the tail, dorsal side up, with the right or gloved hand, and is gently held against the spawner's body with the left. The left hand is then maneuvered into position to allow manipulation of the hand in such a way that the fish is gently stroked from the ventral side, and sufficient pressure is applied to bring the eggs from the fish into the spawning pan (Figure 12).

Incision Spawning Method (Salmon)

There are five species of Pacific salmon, all of which die after spawning. They are:

(a) King salmon.

Other common names: chinook salmon, quinnat salmon, tyee salmon, and spring salmon.

(b) Silver salmon.

Other common names: coho salmon, silversides, and hookbill salmon.

(c) Pink salmon.

Other common name: humpback salmon.

(d) Chum salmon.

Other common name: dog salmon.

(e) Sockeye salmon.

Other common names: red salmon and blueback salmon.

The nonanadromous form of the red salmon, introduced and established in certain California waters, is known as the kokanee, but elsewhere has also gone under the names of little redfish and silver trout.

Only two species, the king and silver salmon, are common in California. Since all Pacific salmon die after spawning, no advantage is derived by stripping the females. Instead, they are killed by a blow on the head and the incision spawning method is used. Milt, however, is stripped from the males, which may or may not be killed.

When taking salmon eggs by the incision method, at least three men are required. The holder grasps the female by the gill cover with a gloved hand and holds the head of the fish about waist-high, with the tail hanging straight down and over the spawning pan. The spawn-taker, from a sitting position, grasps the fish by the tail with one hand and holds the tail away from the spawning pan (Figure 14). This eliminates slime from dripping into the pan. He then makes an incision in the side of the fish with a blunt-tipped knife, starting just behind the pectoral fins and slightly to one side of the median ventral line and continuing to the genital papilla. Eggs begin to fall into the spawning pan when the incision reaches a point just above the ventral fins. The spawntaker then spreads his fingers apart and holds the body open so the ripe eggs will all fall into the spawning pan (Figure 15). No attempt should be made to force out any eggs still clinging to the ovaries. The person spawning the male sits to one side of the spawning pan and strips the milt from the male as required, making sure that each pan of eggs taken receives sufficient milt to fertilize them. Usually about a fluid ounce is used. Water is then added and the eggs in the pan are stirred.

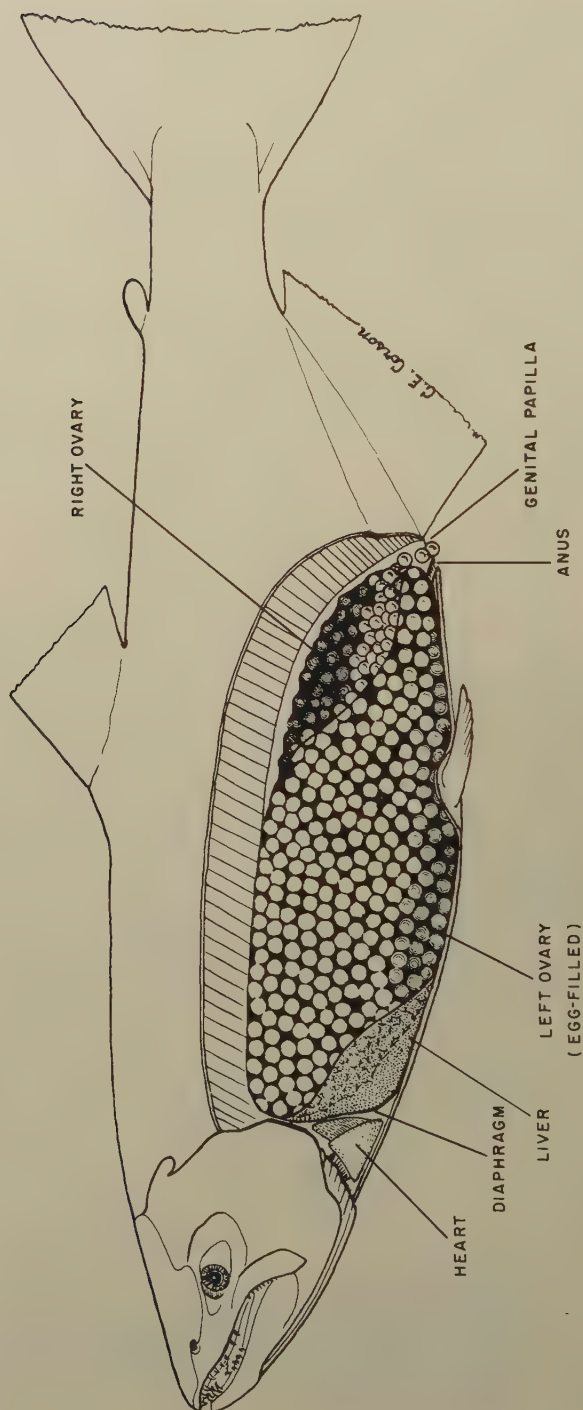


FIGURE 13. Ripe female king salmon.



FIGURE 14. Taking king salmon eggs by the incision method. *Photograph by Harold Wolf, November, 1958.*

Bleeding of female salmon, to prevent excessive blood from entering the spawning pan, is not practiced in California state hatcheries. It is routine at most federal hatcheries. Blood, in its uncoagulated state, is an isotonic solution and, therefore, does not interfere with fertilization. Blood clots, however, prevent the spermatozoa from penetrating the eggs and, if present in excessive amount, may lower fertility. Bleeding of salmon females is done by slashing the caudal peduncle



FIGURE 15. Incision is held open by spawntaker so that all ripe eggs will fall out while sperm from male fish is being added. Photograph by Harold Wolf, November, 1958.

with a sharp instrument or by slitting the isthmus of the fish just anterior to the pectoral fins, thus severing the main artery and allowing the fish to bleed for several minutes before taking the eggs.

Effect of Light on Trout and Salmon Eggs and Alevins

Nature provided that both trout and salmon eggs be shielded from light, especially from the direct rays of the sun. It has been proven that trout and salmon eggs are killed when exposed to direct sunlight for more than a few minutes at a time. In the modern egg incubator, in which trays are stacked one on top of another, the eggs are well shielded from light. In trough hatching, in which eggs are held in baskets, it is common practice to protect them from light by covering the baskets. The following incident may be cited. A trough cover, having a fairly round hole about two inches in diameter, was used. Sunlight shining through this hole killed the eggs which it reached, leaving a group of dead eggs about the size and shape of the hole in the cover.

Experiments with sockeye salmon eggs and alevins incubated in complete darkness showed decided physiological differences between them and eggs and alevins exposed diurnally to indirect daylight encountered in normal hatchery operations. Some of the observed major differences were as follows:

1. The light-exposed eggs hatched earlier than the eggs incubated in natural darkness.
2. The light-exposed alevins showed a decided negative reaction to light and constantly attempted to escape into a darker area, if available.
3. The light-exposed alevins were extremely active, while the alevins in the dark environment were relatively inactive.
4. The total mortality of eggs and alevins was greater when they were light-exposed.
5. Tests of both terminal swimming speed and swimming endurance showed that the fry which had been exposed to light during incubation and the post-hatching period were significantly weaker than those which had not been exposed to indirect daylight.
6. The light-exposed fry were smaller than the fry which had been produced in darkness and averaged one more vertebra.
7. The light-exposed alevins reached the "emerging fry stage" earlier than did the dark-exposed alevins.

The susceptibility of rainbow trout eggs to light is further indicated by experiments to test the possibility of shortening the incubation period with infrared ray lamps. In two experiments, first at Mt. Whitney Hatchery and later at Mt. Shasta Hatchery, all eggs exposed to the infrared light rays were killed. Harmful effects have also been reported when fluorescent lighting was used over incubating eggs. It seems doubtful that the small amount of ultraviolet rays emitted by fluorescent lights is harmful to trout and salmon eggs, and there is nothing to really substantiate this claim. However, to be on the safe side, it seems best to use incandescent lights. In any event, *always shield trout and salmon eggs and alevins from direct light rays.*

MEASURING EGGS

Newly-taken or green eggs may be handled and measured as soon as they become water-hardened, and for roughly 48 hours afterwards, depending upon the water temperature. Green eggs should never be handled or moved unnecessarily during the water-hardening process, nor after they are 48 hours old or more, when development speeds up and the first stage of tenderness begins.

Remember that eggs are sensitive to mechanical shock at all times and that reasonable care must be exercised in handling them.

Several methods for measuring and counting eggs have been developed. Although all have certain shortcomings, the California volumetric method, described here with two other well-known methods, was adopted many years ago because of its accuracy and simplicity. Whatever method is chosen, for proper accuracy it is extremely important that the prescribed techniques and equipment be used.

California Volumetric Method

Equipment used in the volumetric method consists of the following (Figure 16): A, egg-counting board; B, straight-sided graduated beaker; C, 10-ounce measuring cup; D, 2-ounce measuring cup; E, bulb and egg-picking tube; F, trimmed turkey quill.

In nearly all cases both green and eyed eggs are measured from a pail into the baskets or trays. In order to obtain an accurate count, the pail should contain just enough water to cover the eggs at all times. Surplus water in excess of that required to cover the eggs should be poured off. After a portion of the eggs has been measured out, it may become necessary to add a small amount of water. The water in the pail provides a cushion and prevents the eggs from being injured by the measuring equipment. It also allows them to flow readily into and out of the measuring cup. Care should be taken never to jolt or jar a pail of eggs. In filling the measuring cup, it should be dipped into the eggs, completely submerged, and filled until it overflows. In emptying the cup, it should be tilted slightly to one side and the eggs allowed to flow from it. *Never allow the eggs to fall as they are being poured.*

The small two-ounce cup is used as the unit measure in checking for count, and with it the number of eggs per liquid ounce is determined. It should be filled to overflowing. *Avoid compacting eggs into cup by shaking or pressure. Scrape off surplus eggs with an egg-picking pipette.* The cup should be emptied into the egg-counting board and the trimmed turkey quill used to spread the eggs into the holes in the counting board. To assist in making the count, the counting board is marked off in squares of 25 holes each. The eggs in at least two or three small cups should be counted in making the check, the average being used in determining the number per ounce.

The large cup holds exactly 10 liquid ounces and is to be used in measuring the eggs into the baskets or trays. Like the small cup, it should be filled to overflowing each time and the surplus eggs scraped off.

The graduated beaker, like the small and large cups, must have straight sides with the ounce graduations marked thereon. It is used in

determining the number of ounces that remain at the end, when there is less than a full cup left.

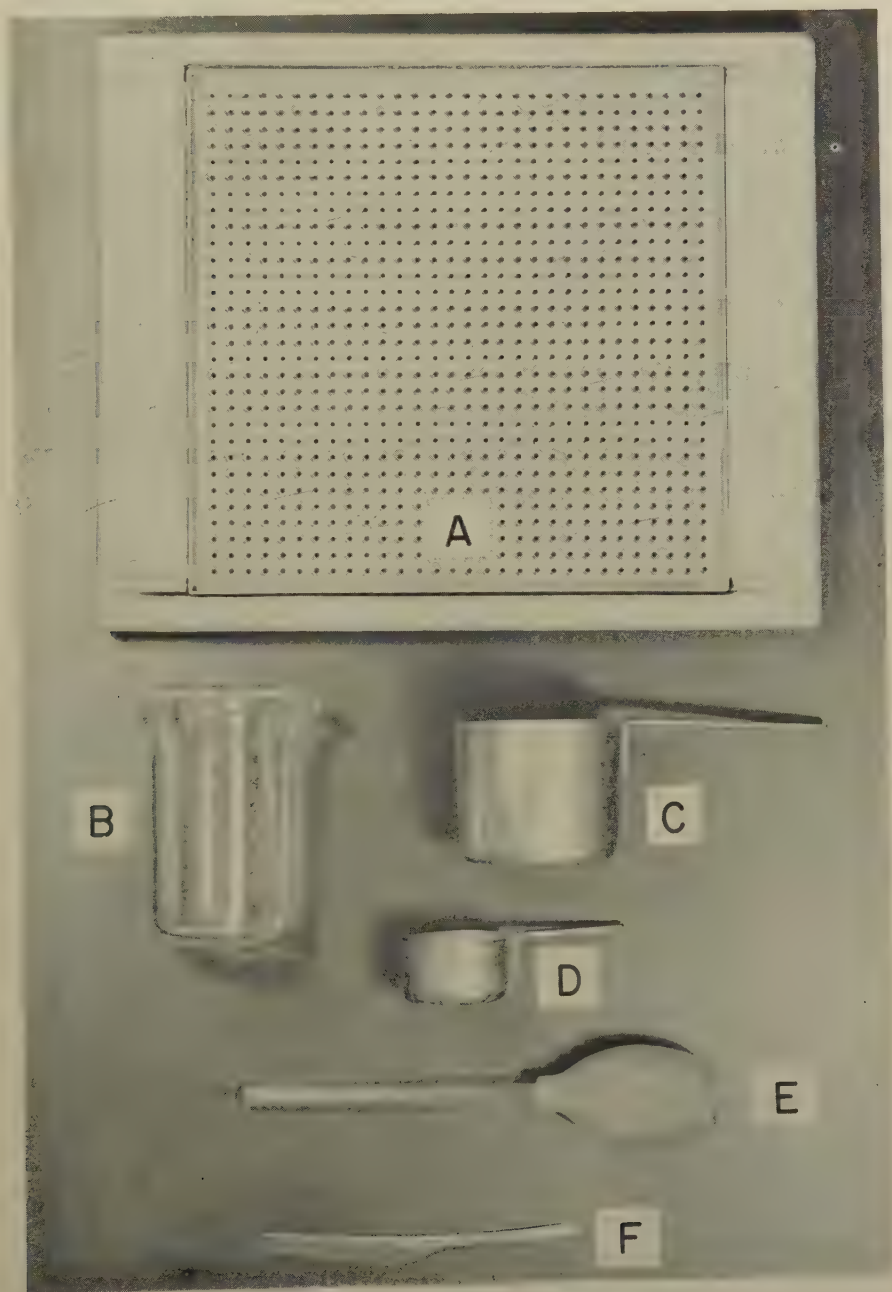


FIGURE 16. Egg-measuring equipment. A, egg-counting board; B, straight-sided graduated beaker; C, 10-ounce measuring cup; D, 2-ounce measuring cup; E, bulb and egg-picking pipette; F, trimmed turkey quill. Photograph by J. H. Wales, May, 1958.

After the eye spots appear, trout and salmon eggs can be handled without any great danger of injury, so long as they are not subjected to unusual shock, freezing, or dehydration.

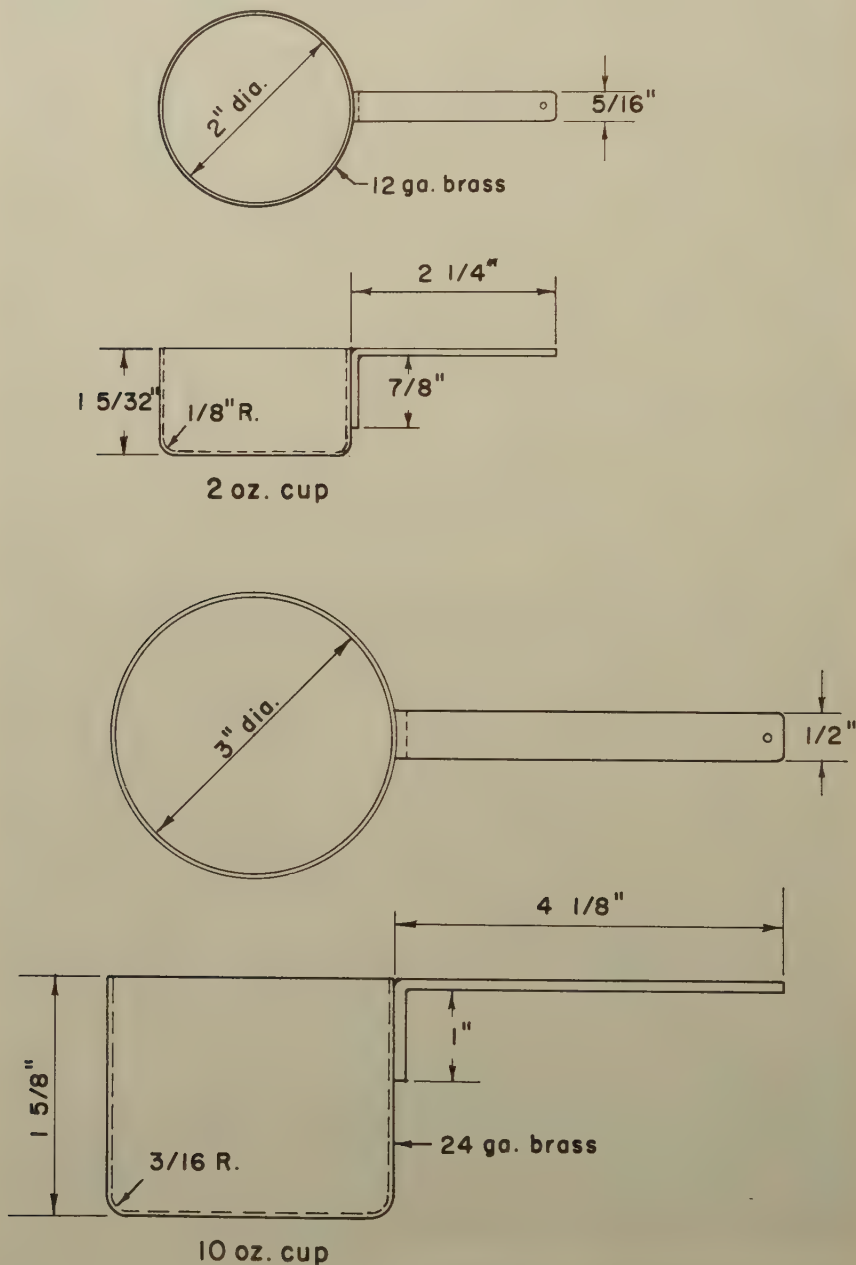


FIGURE 17. Egg-measuring cups.

Burrows Displacement Method

A displacement method has also been developed to enumerate salmonid eggs. This technique utilizes the volume of water displaced by the eggs. Two steps are involved in the technique: (1) measurements to determine the volume of water displaced by all the eggs, and (2) sampling to determine the number of eggs per fluid ounce of water displaced. This technique substitutes an accurately read water level, which has been displaced by the eggs, and provides a method for accurate measurements. The sampling technique, devised for the determination of the number of eggs per fluid ounce of water displaced, exactly duplicates the conditions of the volumetric method and thus automatically compensates for changes in the character of the eggs. Any greater accuracy, however, is attained at the expense of additional equipment and added time.

Von Bayer Method

The Von Bayer method employs a trout egg-measuring trough (Figure 18). The trough is exactly 12 inches long, inside dimensions, having an angle of 45 degrees and a depth of approximately two inches. On the left side of the trough is a scale showing the number of eggs. On the right side is a scale indicating the number of eggs per ounce. Eggs are hand-counted as they are placed in a single row in the trough. If 60 eggs are placed in the trough and the Von Bayer scale is read

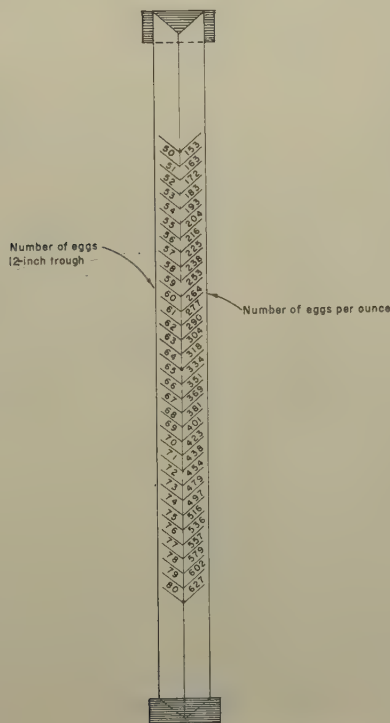


FIGURE 18. Von Bayer trout egg-measuring trough.

opposite the figure 60, it will indicate 264 eggs per ounce. After the number of eggs per ounce has been determined from a sample, the rest are measured with a standard beaker or other acceptable utensil in fluid ounces, and the number of ounces is multiplied by the number of eggs per ounce.

SHOCKING OR ADDLING EGGS

The term shocking or addling trout and salmon eggs is applied to the process of turning the infertile eggs white so they can be separated from the fertile ones. Actually, this amounts to nothing more than agitating the eggs enough to rupture the yolk membrane in the infertile



FIGURE 19. Shocking eggs by the siphon method. *Photograph by J. H. Wales, June, 1958.*

eggs, which causes them to turn white. Eggs can be shocked by stirring them in the basket with the bare hand. However, this may injure some of the good eggs by striking them against the sides and bottom of the basket. By far the safest and best way to shock eggs is to siphon them through a $4\frac{1}{2}$ -foot length of common garden hose from an egg basket in a hatchery trough to a pail on the floor (Figure 19). The pail should be perforated near the top edge, to allow the water to run off without carrying away the eggs. The distance from the end of the hose to the water surface in the pail will determine the degree of shock being given and can be varied until the desired results are obtained. *Trout and salmon eggs should not be shocked until the eye spots are clearly visible.*

PICKING EGGS

Pipette Method

Unless a fungicide is used to prevent dead eggs from fungusing and the fungus spreading to the fertile ones, it is necessary to remove the dead eggs. This is called egg picking.

Various methods have been developed to separate the white or dead eggs from the fertile ones. At one time, nearly all egg picking was done with a large pair of metal tweezers, a tedious process. A great improvement in technique was made when the pipette became universally adopted for picking eggs. It consists of a length of glass tube about eight inches long inserted into the bulb of an infant syringe. The inside diameter of the glass tube should be just large enough to pass the eggs. An experienced operator can pick eggs with a pipette quite rapidly. The operation, however, is quite tiring and can cause serious eye strain. In California, the pipette is used mostly for picking out small numbers of eggs preparatory to shipping. In making up pipettes for egg-picking work, the following materials are recommended:

Bulb, Goodrich, infant syringe, red, 2 ounces, No. 223, or 3 ounces, No. 224.

Tube, Pyrex, clear glass, 6-inch length, thickness of glass 1 mm. or more depending on inside diameter. The inside diameters of tubes commonly used are as follows:

- 5 mm.—0.197 inches for eastern brook trout
- 6 mm.—0.236 inches for small brown trout
- 7 mm.—0.276 inches for brown and small rainbow trout
- 8 mm.—0.315 inches for rainbow trout
- 9 mm.—0.354 inches for steelhead
- 10 mm.—0.394 inches for silver salmon
- 11 mm.—0.443 inches for king salmon

Siphon Egg-Picking Method

Various types of continuous-flow, siphon-type egg pickers have been developed, and great claims have been made for them. The continuous-flow, siphon egg picker consists of the pipette with bulb, and a length of flexible hose reaching from the bulb at working height to a pail on the floor. The siphon is started and the egg picker moves the glass tube in the basket of eggs in much the same way as when using the pipette alone. The flow of water through the siphon hose is controlled by applying pressure to the syringe bulb, located between the end of the glass

tube and the upper end of the siphon hose and held in the hand. Eggs can be picked faster with a siphon than with a pipette, because it is not necessary to empty out the bulb as is done with the pipette, since the eggs picked up are siphoned into the pail on the floor. A modification of the siphon egg-picking device is the power egg picker described in the article, "Power Egg Picker", by R. J. McMullen (1948).

Salt Flotation Method

The flotation method is one of the older methods still used to some extent. A salt box in which a standard egg basket will fit is used. The salt box is filled with water to nearly overflowing and common stock or table salt is added and stirred into the water until a solution of the proper strength is reached. The amount of salt to be added can best be determined by dipping up a sample of the solution in a glass container, preferably a quart fruit jar, and then dropping a few eggs into the jar, using both live and dead eggs. If the solution is right, the dead or bad eggs will float and the live or good eggs will slowly settle to the bottom. If both good and bad eggs float, the solution is too strong and should be diluted by adding water. If both good and bad eggs settle to the bottom, the solution is too weak and more salt should be stirred in. The margin at which the salt solution will separate the good eggs from the bad is quite narrow, so great care must be taken in the preparation of the solution. When a solution of the proper strength has been attained, the basket containing the eggs is set into the salt box, and after a moment or two the good eggs begin to settle to the bottom. The bad eggs floating on top are then skimmed off with a small scaph net. Care must be taken in skimming off the dead eggs and any turbulence created by the scaph net must be kept down, since any movement of the water will cause the good eggs to rise to the surface and mix with the bad. The eggs in a basket should not be over one inch deep for salting, regardless of the size of the eggs. Separation becomes more difficult with more than that amount.

For satisfactory salting, trout eggs should be well eyed. The further the embryo has developed, the more rapidly will the eggs settle in the salt solution. Eggs should be shocked at least 36 hours before salting, for good results. As the solution becomes diluted, more salt should be added. A salinometer may be used to determine the strength of the solution.

Once the strength of the solution has been determined, it is easy to maintain it by periodic testing. The optimum strength may vary with different lots, depending on the stage of development and the elapsed time between shocking and salting.

Flush Treatment to Eliminate Egg Picking

Egg picking, once a tedious and time-consuming process and still practiced at most hatcheries, has been found entirely unnecessary at others so long as fungus can be controlled. To eliminate egg picking, trout and salmon eggs are flushed once each day with a malachite green solution from the day they are taken until hatching commences. The solution is made by dissolving $1\frac{1}{2}$ ounces, dry weight, of malachite green in one gallon of water. The flow in the hatchery trough is regulated to about six gallons per minute and then three liquid ounces of

the stock solution are added to the upper end of the trough. As soon as the water in the trough has cleared, the flow is increased to normal. The strength of solution, water flow, and time required to flush are not extremely critical.

After the basket or tray of eggs has finished hatching, the dead eggs are disposed of. By previously having determined the percentage of fertilization, egg losses can be computed quite accurately. At locations where hatchery water flows through outside ponds, the flush treatment should not be done at feeding time.

TROUT EGG BASKETS

The popularity of egg incubators for incubating and hatching fish eggs is increasing rapidly and the several advantages of the egg incubator are explained in another section. However, most of the salmon and trout eggs hatched in California are still handled in egg baskets suspended in hatchery troughs.

The standard California egg basket is 24 inches long, $14\frac{1}{2}$ inches wide, and 6 inches deep. The outer frame to which the formed basket is attached is made of wood molding $1\frac{1}{2}$ by $\frac{3}{4}$ inches. Egg basket mesh is a specially woven material with rectangular openings which prevent the round eggs from falling through. The newly-hatched alevins, on the other hand, being elongated and quite compressible, easily fall through

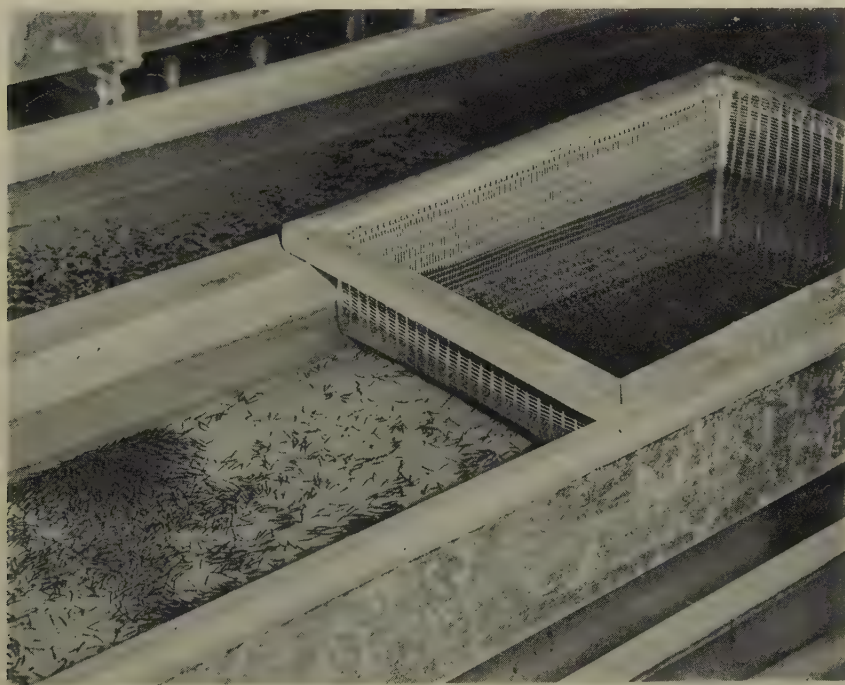


FIGURE 20. Trout eggs hatching in egg basket. Note newly-hatched alevins which have fallen through rectangular mesh into the trough. Photograph by J. H. Wales, January, 1959.

the rectangles into the trough (Figure 20). When all of the fertile eggs have hatched, the basket is removed and the dead eggs disposed of.

Wire basket mesh is woven on order only and is available in rolls 27 inches wide and 100 feet long.

The material is known in the trade as mesh cloth, triple warp, and can be woven in a variety of sizes. The following description of mesh suitable for hatching rainbow and brown trout eggs will aid in describing basket mesh cloth.

Mesh cloth—triple warp, 5/9-inch mesh, 0.035-inch diameter wire; fill, 7-inch mesh, 0.041-inch diameter wire.

Triple warp refers to the three 0.035-inch diameter wire warp which binds the mesh together, as shown in Figure 20. Five eighths-inch mesh

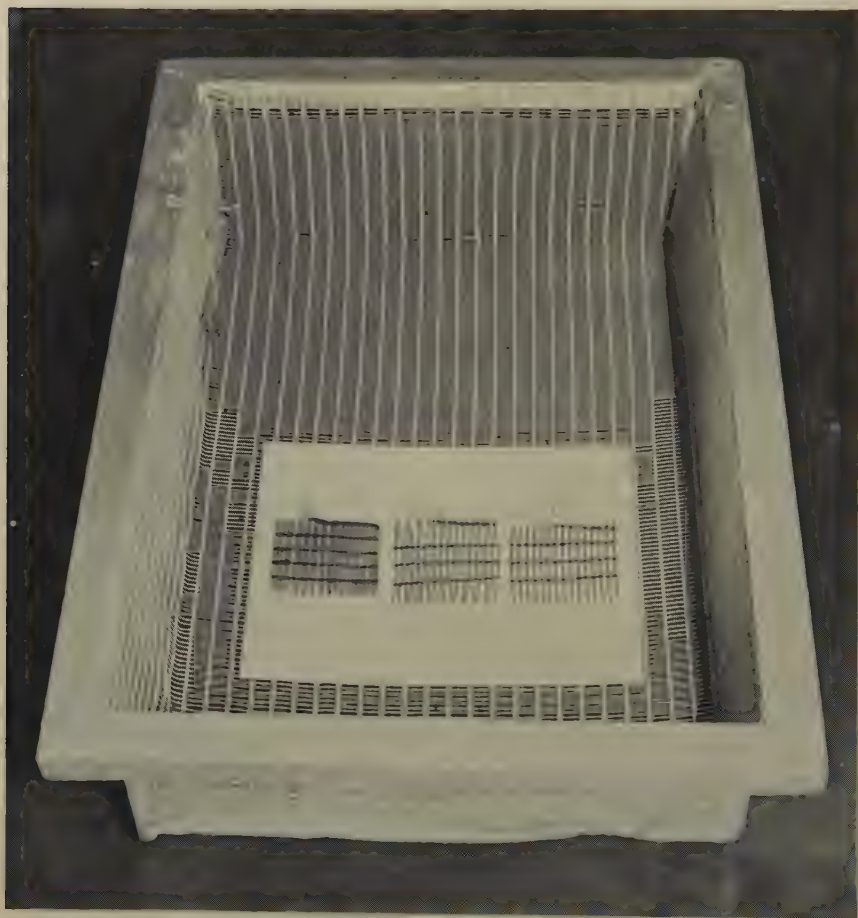


FIGURE 21. Fish egg-hatching basket made of triple-warp mesh cloth. Note the rectangular openings. Swatches on white background show three mesh sizes. Left has 9 meshes per inch for eastern brook and other small eggs from 400 to 700 per ounce. Center has 7 meshes per inch for rainbow and brown trout eggs 240 to 390 per ounce. Right has 5 meshes per inch for steelhead and silver salmon 120 to 280 per ounce. For king salmon eggs 60 to 90 per ounce, 5 meshes per inch are required.

Photograph by J. H. Wales, May, 1958.

indicates the length of the opening. Fill 7-inch mesh indicates that there are seven wires 0.041 inches in diameter per inch, which determines the width of the opening. Mesh cloth is obtainable in galvanized, copper, brass, or aluminum material.

In basket hatching, up to five baskets can be placed in one trough and held until hatching time, and up to 150 ounces of trout eggs or 300 ounces of salmon eggs can be carried per basket. It is absolutely necessary, however, that division plates be placed ahead of each basket in such a way that the water flow will be directly underneath the basket and allowed to well up through the eggs for proper aeration (Figure 22).



FIGURE 22. Wire-mesh fish egg basket suspended in hatchery trough. Note placement of metal division plates. Water flows over first plate and is forced downward by second plate, causing it to rise upward under egg basket for proper circulation.

Photograph by Harold Wolf, February, 1958.

FISH EGG INCUBATORS

Basically, fish egg incubators consist of a number of shallow trays stacked one on top of another and spaced apart by guiding strips, much as drawers in a dresser (Figure 23).

Some of the advantages of the egg incubator are the following: less space is required than for troughs; eggs are easily treated for fungus control; egg picking is eliminated; and, due to the small amount of water required, temperature may be controlled.

One of the first incubators was described by Nordqvist (1893). Since then several kinds have been described and used with varied success. They may be divided into two types: drip and the continuous or vertical flow. In the drip incubator, eggs are placed in the trays as soon as they are water-hardened and kept there until ready to hatch, at which time they are transferred to troughs. In the vertical flow incubator they are allowed to hatch there. The alevins remain in the trays until ready to feed. In general, the two types differ mainly in the way in which the water comes in contact with the egg.

Incubators have several advantages over the conventional trough and basket method for incubating and hatching eggs. The small amount of water required, $3\frac{1}{2}$ gallons per minute for a 20-tray incubator, permits recirculating and either heating or cooling the water to speed up or delay development, whichever may be desirable. Fungus can be effectively controlled and egg picking entirely eliminated. The amount of space required for incubators is far less than that required for troughs of equal capacity. Eggs are shielded from light and much of the equipment incidental to trough hatching, such as baskets, basket covers, and division plates, is not required.

Drip Incubator

In the drip incubator, water is introduced into the top or distribution tray and gently drops from one tray to another down through the entire stack, providing sufficient moisture for egg development. A drip incubator which has proven satisfactory at Mt. Shasta Hatchery contains 20 removable trays placed in four compartments of a wooden framework. The five trays of each compartment consist of a metal diffusion tray with perforated metal bottom and four egg trays with screen bottom, resting each upon another. A metal pan with a hose fitting under the lowermost compartment collects the used water, so that it can be drained off.

The drip incubator is used only for incubating eggs from the time they are water-hardened until just before they are ready to hatch. Egg picking is entirely eliminated and fungus is controlled by treating the eggs with a malachite green solution. The procedure is as follows: On the day after the eggs are taken, the loaded egg trays are stacked four high in a standard hatchery trough and held one inch off the bottom of the trough by a spacer. Water flow is adjusted to six gallons per minute and the eggs are given two standard flush treatments of malachite green at 8 a.m. and 5 p.m. (A treatment consists of three ounces of a stock solution made by dissolving $1\frac{1}{2}$ ounces of dry malachite green in one gallon of water added to the upper end of the hatchery trough containing the eggs.) The malachite green solution is forced up through the eggs by means of division plates, and after

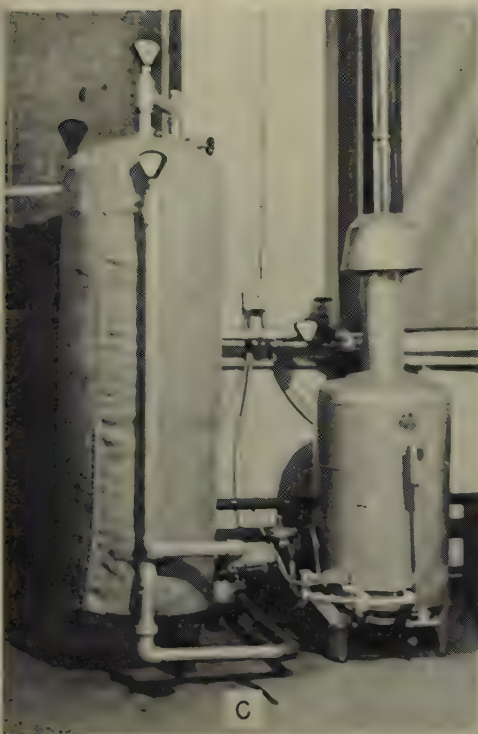


FIGURE 23. A, all metal vertical flow incubator with temperature-controlled water supply; B, mechanical refrigeration unit; C, gas-fired water heating unit; D, water filter used in conjunction with incubator. Photograph by Harold Wolf, 1958.

the second treatment the trays are transferred to the incubator for development.

To control fungus during the incubation period, the eggs are treated twice each week with malachite green solution. The solution is made by dissolving 3.75 grams or 56 grains of dry malachite green in 3,000 cc. of water. The water flow through the incubator is set at about two gallons per minute, and the solution is allowed to drip into the top tray at the rate of 30 cc. per minute for a period of one hour.

When the eggs are ready to hatch they are transferred from the incubator trays to egg baskets. When hatching is complete, the basket is removed and the dead eggs are measured.

Vertical Flow Incubator

In the vertical flow incubator the trays actually consist of two compartments: first, the basket with cover in which the eggs are held, and second, the tray in which the basket rests. The trays are stacked one on top of another, as in the drip incubator. Water flows from a tray to the tray immediately below, until it is drawn off at the bottom. The water is introduced to the bottom of each tray in such a manner that it wells up through the basket containing the eggs. This provides sufficient aeration for their development. In the vertical flow incubator, the eggs are allowed to hatch and the alevins remain in the trays until ready to feed. For this reason, the trays must be covered to prevent the newly-hatched fish from escaping. Fungus is controlled with malachite green treatments in the same way as in the drip incubator previously described.

When the fish have absorbed their yolk sacs and are ready to feed, the tray units should be moved to troughs or tanks, placed on the bottom, cover screens removed, and the fish allowed to swim out. Dead eggs and deformed fish will remain in the egg tray and can be counted and then discarded.

Roberson, Inc., 1539 East 103rd Street, Seattle 55, Washington, manufactures both drip and vertical flow incubators made entirely of fiberglass. Experiments conducted with a Roberson incubator at the Mt. Whitney Hatchery, where water temperatures can be controlled either by heating or cooling, gave the following results.

1. One hundred ounces of rainbow eggs at 450 per ounce (45,000 eggs) were eyed in one tray at a temperature of 52 degrees with negligible loss.

2. Eighty ounces of rainbow eggs at 450 per ounce (36,000 eggs) were hatched at constant temperatures of both 42 degrees and 52 degrees and carried in the trays until they approached the swim-up stage.

3. Water which naturally fluctuated from 40 to 59 degrees during the time of the experiment was maintained at a constant temperature of 42 degrees and development was retarded and hatching delayed by about four weeks.



FIGURE 24. A, 20-tray Roberson vertical flow incubator—only $3\frac{1}{2}$ gallons of water per minute required to incubate over 140,000 trout eggs; B, incubator tray made of corrosion resistant fiberglass; C, water is reaerated by flowing over end of tray into the tray below; D, incubator tray filled with king salmon eggs; E, egg-filled tray with cover in place. Photographs by Roberson, Inc., Seattle, Washington, 1958.

PACKING EGGS FOR SHIPMENT

Green Eggs

Green eggs may be shipped for a period of up to 48 hours after being taken. Normally, when green eggs are transported only a short distance they are placed in 10-gallon milk cans filled with water. This



FIGURE 25. Lightweight egg shipping case made of marine plywood. Egg trays are made of 1 in. x 1/2 in. wood molding, covered with common window screen and painted with asphaltum varnish. Bottom tray shown in upper right of picture is turned bottom side up to show the two wood cleats which hold the tray up from the bottom of the case. Egg trays are 14 in. x 14 in. x 1 in. and will hold 70 ounces of eggs regardless of the number per ounce. The case holds 20 egg trays. Both ends of the egg case and the top ice tray are filled with cracked ice before shipping. Melting ice in the ice tray drips down through the eggs, keeping them moist. Photograph by George Farnham, February, 1958.

method is quite satisfactory so long as severe jolting and rise in temperature are prevented. Care must be taken not to place too many eggs in a can. It must be remembered that trout and salmon eggs increase in size by about 20 percent during the water-hardening process, and if too many eggs are placed in a can the eggs near the bottom may be killed by the resulting pressure from the eggs above. A simple way to prevent excessive pressure on the eggs in the bottom portion of the can is to measure out eggs in amounts of 50 ounces each and place them on pieces of mosquito netting about 18 inches square. The four corners of the netting are then picked up and tied with a string. The eggs can then be suspended at different depths in the can by varying the length of the suspending string.

Eyed Eggs

Eyed salmonid eggs have been shipped to all corners of the world in a variety of shipping containers. Figure 25 shows a lightweight egg case suitable for railway express shipments. In selecting shipping containers, one should bear in mind that eyed eggs must be kept cold to prevent their hatching en route.

Good judgment is necessary on the part of the hatcheryman when making egg shipments. Eggs must be kept moist to prevent dehydration and containers should be light to keep shipping charges at a minimum and should protect the eggs as much as possible against sudden shock. Eggs should not be so far advanced that they will hatch en route and the resulting alevins lost. The temperature in a shipping case is usually higher than that of most hatchery waters and fungus will grow very rapidly on dead eggs if they are left in the shipment. For shipping purposes, eggs should be sufficiently eyed to permit shocking, so that the infertile eggs can be removed.

The term eyed eggs is used rather loosely in hatchery practice and is usually applied to the eggs any time after the eye spots are visible to the unaided eye.

Shipping Eggs by Air

Air shipments of fish eggs must be made with leakproof containers. The following method has proven satisfactory in making air shipments to Brazil. The cases were not opened or re-iced in transit and the eggs arrived safely after a lapse of 36 hours.

Materials required for air shipping cases:

- 1 fiberboard ice-cream carton, 16 in. x 16 in. x 27 in. high, with insulated liner.
- 20 screen-bottom egg trays, 14 in. x 14 in. x 1 in. deep; the same as used in the previously described lightweight egg shipping case.
- 1 heavy plastic bag (liner), made by seaming two 36 in. x 48 in. sheets around the edges on all but one end.
- 1 roll Scotch filament tape, No. 880, $\frac{3}{4}$ in. wide.
- 1 roll 3-ply, twisted sisal twine.

Procedure: (1) Insert the insulated liner into the fiberboard carton. (2) Pack two egg trays with dry moss for use on bottom stack of trays. (Sufficient moss must be placed on the bottom two trays to hold the eggs above all of the water which will accumulate from melting ice. If



FIGURE 26. Leakproof, insulated egg-shipping case for shipping eggs by air.
Photograph by J. H. Wales, April, 1959.

the lower trays become submerged in water while in transit, the eggs on the submerged trays will smother.) (3) Pack the next 17 trays with either trout or salmon eggs, about 60 ounces per tray. (4) Place one empty tray on top of the stack of 19 trays. (5) Bind the entire stack of 20 trays together with filament tape. (6) Insert the stack of bound trays into the plastic bag, and then slip the entire contents into the insulated carton. (7) Add crushed ice, about five inches deep, to the top empty tray. (8) Loosely fold down the plastic bag and insulated liner. (9) Cut two breather holes, about one inch in diameter, one on each side near the top of the fiberboard carton. (10) Close carton top and secure with filament tape. (11) Bind the carton with sisal twine, to reinforce.

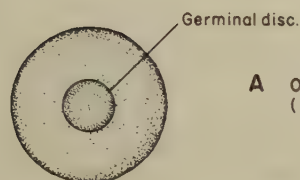
When packing eggs by the above method, it is imperative that the fiberboard container remain dry. It is best to keep it in a plastic bag, to prevent water being spilled on it. Excess water should be drained off each egg tray before stacking the trays.

After the eggs have been unpacked, the insulated liner may be disposed of. The fiberboard carton can then be cut down and used to return the trays and plastic liner.

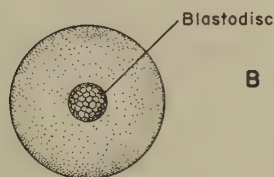
DEVELOPMENT OF TROUT AND SALMON EGGS

Trout and salmon eggs undergo a continuous developmental change from the time they are taken until they hatch. The rate of development is dependent on water temperature. During this period there are several changes or stages which are important for fish culturists to recognize. Important stages may be briefly summed up as follows:

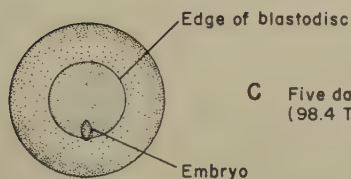
1. *Fertilization.* This takes place within seconds after the eggs are taken and is dependent on several factors, such as degree of ripeness of the male and female fish, viability of both sperm and ova, and technique of the spawntaker.



A One day after fertilization, at average temperature of 55.9° F. (23.9 T.U.).



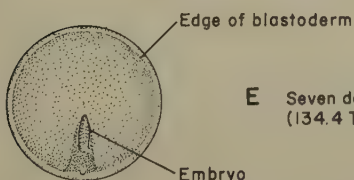
B Two days after fertilization, at average temperature of 53.9° F. (43.9 T.U.).



C Five days after fertilization, at average temperature of 51.7° F. (98.4 T.U.).



D Six days after fertilization, at average temperature of 51.5° F. (117.0 T.U.).



E Seven days after fertilization, at average temperature of 51.2° F. (134.4 T.U.).

FIGURE 27. Development of steelhead trout eggs.

2. *Water hardening.* This is the period during which the egg absorbs water and becomes firm and slick. From the time the egg becomes water-hardened and for a period up to 48 hours, depending on water temperature, newly-taken trout and salmon eggs may be measured and shipped if this is carefully done.

3. *Tender period.* Trout and salmon eggs become progressively more tender during a period extending roughly from 48 hours after water hardening until eyed. The extreme critical period for steelhead trout eggs is entered into on the seventh day in water having a temperature of 51 degrees F. (Figure 27E) and extends through the ninth day

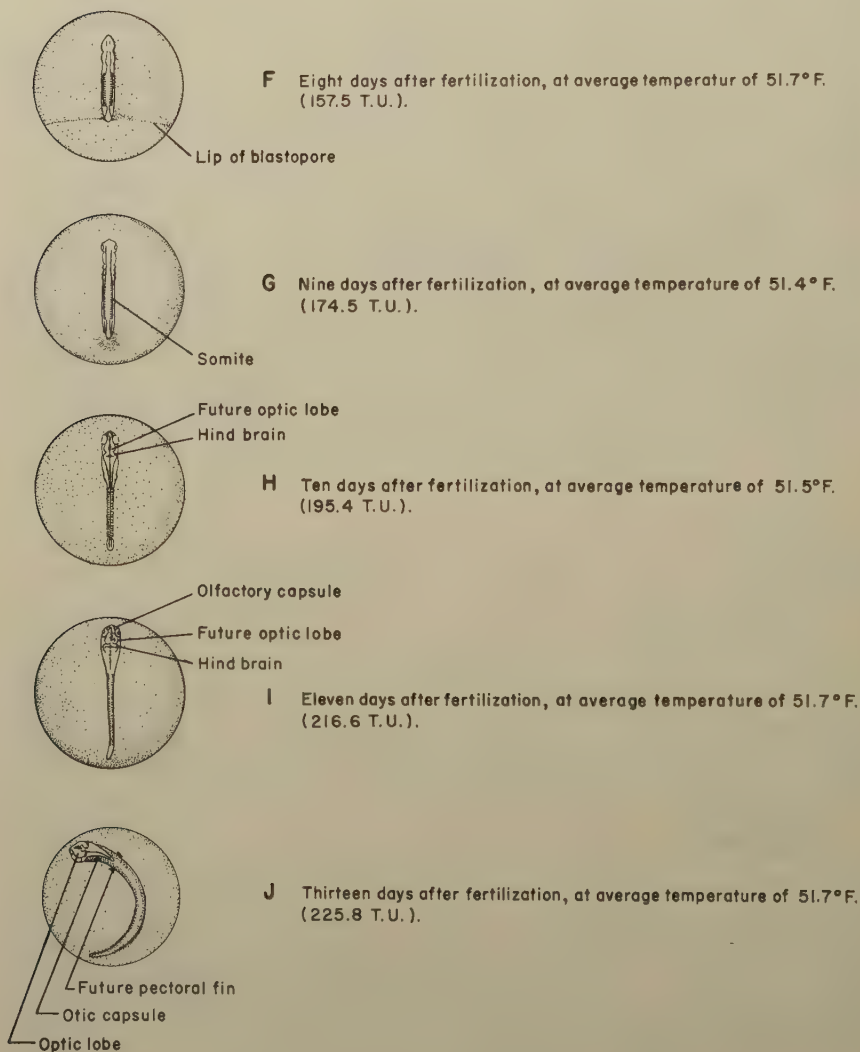
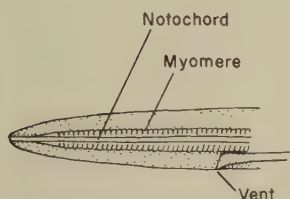
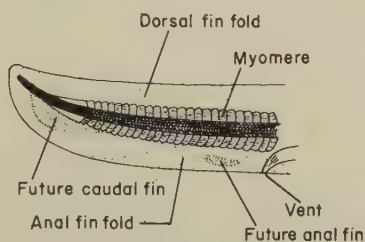


FIGURE 27—Continued

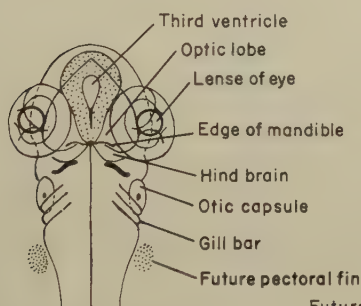
(Figure 27G), at which time the blastopore is completely closed. It is common practice to work or pick eggs from the second day after taking until the critical period is reached. Then they are not touched until the



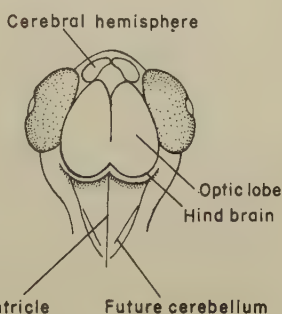
K Fourteen days after fertilization, at average temperature of 51.5°F (273.2 T.U.).



L Sixteen days after fertilization, at average temperature of 51.7°F (315.9 T.U.).

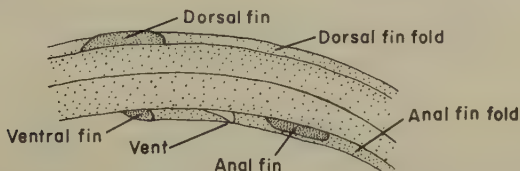


HEAD-VENTRAL VIEW



M Sixteen days after fertilization, at average temperature of 51.7°F (315.9 T.U.).

N Eighteen days after fertilization, at average temperature of 51.8°F (357.4 T.U.).



O Twenty-six days after fertilization, at average temperature of 51.2°F (500.4 T.U.).



critical period has passed. This is usually referred to as the period during which the eggs are closed. Even though the critical period for steelhead eggs has passed on the ninth day at 51 degrees F., the eggs remain tender until the 16th day, when the eyes are sufficiently pigmented to be visible.

4. *Eyed stage.* As the term implies, this is the stage from the time the eye spots become visible until the egg hatches. During the eyed stage, eggs are usually addled, cleaned up, remeasured, shipped, or set out for hatching. The oxygen requirement for trout and salmon eggs increases as the embryo develops and smothering of eyed eggs in baskets or incubator trays must be prevented.

Temperature Units

For many years temperature units were used by hatcherymen to estimate the length of time required for trout eggs to develop, and it was believed that the total number of units was constant for any species regardless of the average temperature throughout the incubation period.

One temperature unit (T.U.) equals one degree Fahrenheit above freezing (32 degrees F.) for a period of 24 hours. For example, if the average water temperature for the first day of incubation was 55.9 degrees F., it would constitute 23.9 T.U. (55.9 degrees minus 32 degrees). If, on the second day, the temperature averaged 52 degrees F., it would add 20 more T.U., or a total of 43.9 to the end of the second day.

Table 4 shows how great are the variations in temperature units at different water temperatures. It clearly demonstrates that they are not a safe measure for the trout culturist. They are included here in the tables and drawings only for the purpose of illustration.

TABLE 4
Number of Days and Temperature Units Required for Trout Eggs to Hatch *

Water temperature in degrees F.	Rainbow		Brown		Brook		Lake	
	Number days to hatch	Temperature units	Number days to hatch	Temperature units	Number days to hatch	Temperature units	Number days to hatch	Temperature units
35.....	--	--	156	468	144	432	162	486
40.....	80	640	100	800	103	824	108	864
45.....	48	624	64	832	68	884	72	936
50.....	31	558	41	738	44	799	49	882
55.....	24	552	--	--	35	805	--	--
60.....	19	532	--	--	--	--	--	--

* Spaces without figures indicate incomplete data rather than a proved incapability of eggs to hatch at those temperatures.

In any species of trout, the incubation period or average hatching time of the eggs is not immutably fixed for a given temperature but may vary as much as six days between egg lots taken from different parent fish.

Table 5 shows the day-by-day development of sea-run steelhead eggs. This is further illustrated by Figures 27A through 27P. Other strains of the rainbow group have a similar pattern.

TABLE 5

Record of Daily Steelhead Egg Samples

In the following descriptions a few of the more important facts have been given for each of the daily egg samples. These samples were taken at the same time each day and the temperature units listed refer to the total accumulated up to the time that particular sample was taken.

Number of days since fertilization at average temperature of 51 degrees F.	Temperature units	
1	23.9	Blastodisc without cell division (Figure 27A).
2	43.9	Blastodisc has rounded up and is slightly smaller in diameter; it is composed of three layers of cells (Figure 27B).
3	62.2	Blastodisc slightly larger; cells about $\frac{1}{2}$ the size of those in sample 2.
4	81.1	Blastodisc slightly larger; cells about $\frac{2}{3}$ the size of those in sample 3.
5	98.4	Blastodisc slightly larger; edge thickened; embryo started to form (Figure 27C).
6	117.0	Thickened edge of blastoderm is narrower; embryo with thickenings (Figure 27D).
7	134.4	Blastoderm covering about $\frac{3}{4}$ of the yolk surface; embryo much lengthened and thickened, strongly contrasted against the yolk; eggs are now tender and should not be handled roughly (Figure 27E).
8	157.5	Optic vesicles forming; body with 23 somites; blastoderm covering about $\frac{3}{4}$ of the yolk (Figure 27F).
9	174.5	Blastopore closed; optic vesicles have invaginated; notochord continuous with brain, end of critical period (Figure 27G).
10	195.4	Eye lenses well developed; 32 somites present; otic vesicles starting to form; notochord continuous with brain (Figure 27H).
11	216.6	Cerebral hemispheres evident; segmentation of hind brain begun; 46 somites present; pectoral fins starting to form; notochord ending just anterior to otic capsules; the caudal region apt to be twisted (Figure 27I).
12	236.8	Optic lobes starting to grow over interior-posterior margin of eyes; lenses not quite broken away from ectoderm; notochord ending just posterior to anterior end of otic capsules; 49 somites present (the last 5 have not become myomeres); the embryo covers about $\frac{3}{4}$ circumference of egg.
13	255.8	Lenses have broken away from the ectoderm; 60 somites present (all have become myomeres); 3 gill buds present (Figure 27J).
14	273.2	Fin folds about half as wide as body; tail still homocercal; mouth and gill cartilages faintly evident (Figure 27K).
15	297.8	Tail becoming heterocercal; eyes becoming pigmented.
16	315.9	Four gill buds evident at sides of throat; hereafter there are but slight changes in the brain; the hind brain apparently decreases and the cerebral hemispheres enlarge; anal fin first noticeable here; the eggs are past the tender period and can be handled more roughly (Figures 27L and M).
17	336.6	No apparent changes except in size.
18	357.4	Dorsal fin begins here as a faint thickening; nostrils first evident; gill slits on ventral side extending almost to midline (Figure 27N).
19	377.7	Opercle grown back over first gill bar; traces of melanophores on head and body.
20	395.3	Gill bars have become definite arches; mandible has become pointed up between eyes but still far from maxillary.
21	412.0	Increase in size.
22	430.8	Ventral fins now evident.
23	448.0	Cerebral hemispheres about $\frac{3}{4}$ length of optic lobes.
24	466.6	No apparent changes.
25	485.4	Point of opercle extending back to 4th gill arch, only the distal ends of last 3 exposed.
26	500.4	No apparent changes (Figure 27O).
27	518.7	Mandible apparently stops its forward growth at this stage.
28	535.9	Dorsal and anal fin rays first visible at this age; point of opercle entirely covering first 2 gill arches; hatching begins.
29	556.1	Length of embryo equal to circumference of egg; anal fin shows about 8 rays and dorsal fin shows about 6.
30	573.9	Hatching completed (Figure 27P).

HATCHERY TROUGHS

The standard California hatchery trough is 16 feet long, 16 inches wide, and $7\frac{1}{2}$ inches deep, inside measurements, with a gradient of one inch in 16 feet, and when operated with a 5-inch outlet plug contains roughly 64 gallons of water. The flow through the troughs varies among hatcheries and depends on the temperature and number of eggs or fish being carried in the troughs. On the average, troughs in California hatcheries, regardless of whether they are installed singly or in tandem, receive from 12 to 15 gallons of water per minute. It is intended that the oxygen content be maintained at not less than 7 p.p.m.

At one time, all troughs were made of wood, either cedar or redwood being used. In recent years, the trend has been toward metal (aluminum) troughs (Figure 28). Advantages of aluminum troughs are that the normal tasks such as scrubbing, sanding, and painting are practically eliminated. There is less chance for leakage and the smooth non-porous surface does not provide as great a haven for disease organisms as does the old wooden trough. A wide variety of aluminum alloys, differing in chemical composition and physical properties, have been developed. The various aluminum alloys are designated by numbers,

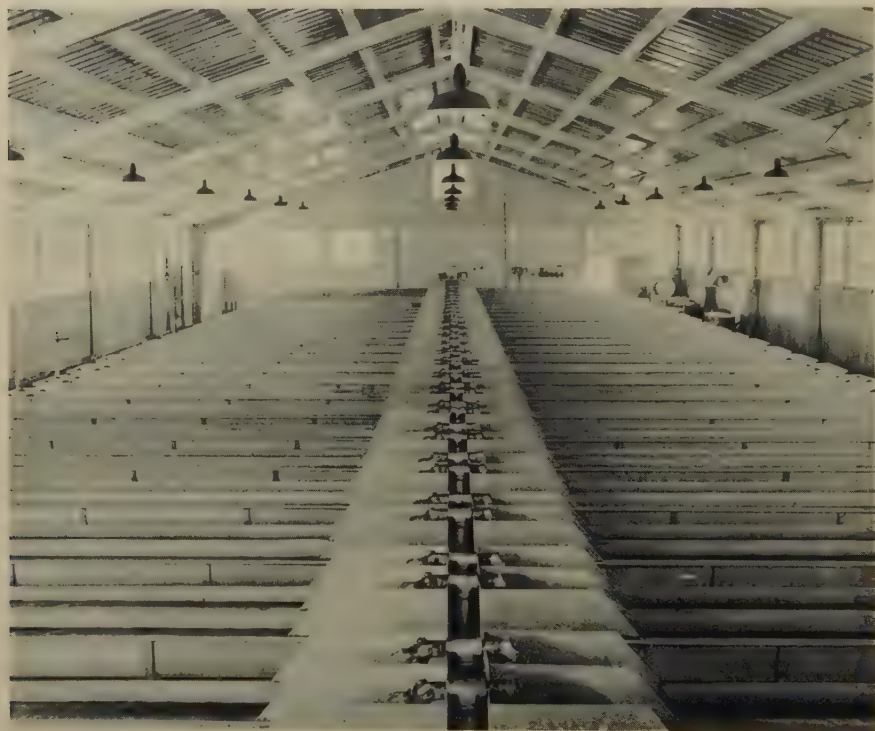


FIGURE 28. Aluminum hatchery troughs. Center water supply permits unobstructed aisle between troughs from one side of building to the other. Photograph by Harold Wolf, July, 1958.

such as 3514- $\frac{1}{2}$ -H, 53ST, etc. A complete nomenclature may be obtained from any of the several large manufacturers of aluminum alloys, and with the aid of this nomenclature the various alloys can be identified.

It is very important for anyone contemplating the installation of aluminum troughs to first obtain a complete chemical analysis of the water at the location where the troughs are to be installed. This analysis should be made available to a reliable aluminum manufacturing company, which will usually furnish competent engineering assistance in selecting the proper alloy.

Trough Carrying Capacity

It is generally agreed that the oxygen requirements for salmon and trout are nearly the same for all species, with rainbow possibly requiring the highest amount, brown trout the next highest, and eastern brook the lowest. Oxygen requirements are increased by activity, feeding, and rise in temperature. While it is desirable to maintain an oxygen level of 7 p.p.m. for holding salmon and trout, the absolute minimum for this purpose is 5 p.p.m. It has been shown that at 45 degrees temperature a yearling rainbow will consume 3 cc. of oxygen per hour, while at 68 degrees consumption will increase to 12 cc. per hour, an increase of 300 percent. The increase in oxygen use, associated with rising temperature, crowding, feeding, weighing, and activity, must be considered when determining the number of fish to place in hatchery troughs and ponds.

Table 6 shows the trough carrying capacity in ounces of trout per gallon per minute of water under conditions indicated.

TABLE 6

Trough Carrying Capacity in Ounces of Trout Per Gallon Per Minute of Water Flow.
Inlet Water Saturated. Outlet Water Oxygen Content 5 p.p.m.*

Temperature in degrees F.	Elevation in feet										
	0	1,000	2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000
	Ounces of trout										
45-----	400	380	350	330	310	285	265	240	225	210	190
50-----	210	195	180	170	160	145	135	120	110	100	95
55-----	132	125	116	107	100	93	83	76	69	62	55
60-----	93	85	80	72	67	62	56	50	45	39	34
65-----	66	61	57	51	46	42	37	33	30	25	21
70-----	52	48	44	39	36	31	28	24	22	18	14

* At lower temperatures and altitudes, actual crowding of fish would become a limiting factor, rather than available oxygen. Thus, at 45 degrees F. and sea level, 20 gallons per minute would supply 8,000 ounces with sufficient oxygen, but that weight of fish would require more than a standard trough to prevent overcrowding.

Table 7 indicates the minimum water requirements in a hatchery trough in gallons per minute for each 1,000 ounces of trout. The tabulated figures are for troughs and are not applicable to rectangular or

TABLE 7

Minimum Water Requirements in Hatchery Troughs in Gallons Per Minute for Each 1,000 Ounces of Trout *

Temperature in degrees F.	Elevation in feet										
	0	1,000	2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000
	Gallons per minute										
45-----	2.5	2.7	2.9	3.0	3.2	3.5	3.8	4.2	4.5	4.8	5.3
50-----	4.8	5.4	5.6	5.9	6.2	6.9	7.4	8.3	9.1	10	11
55-----	7.6	8.0	8.6	9.3	10	11	12	13	15	16	18
60-----	11	12	13	14	15	16	18	20	22	26	29
65-----	15	16	18	20	22	24	27	30	33	40	48
70-----	19	21	23	26	28	32	36	41	45	55	71

* Values above 10 are shown only to the nearest gallon. For tandem troughs with good aerators between upper and lower, the water requirements can be lowered about 10 percent.

circular ponds, in which reaeration from the surface is large in comparison to oxygen directly available from the water supply.

Even though it is not general practice in California hatcheries to install hatchery trough aerators, the oxygen level in troughs can be considerably increased by their use. Reference is made to "Hatchery Trough Aerators", by Paul A. Shaw (1936).

TROUT AND SALMON PONDS

Pools or ponds for rearing trout and salmon have over the years been as varied in design as French fashions. One can understand that in large, deep, still pools, fish rest most of the time and food conversion is normally better than in narrow, swift ponds, where a good portion of a fish's energy is used in maintaining its position in the pond. The ideal pond is one that can be operated rather deep and with little current most of the time, but can be readily converted to a shallow, swift pond when necessary. Deep, still pools have the disadvantage of not lending themselves to flush or prophylactic treatments, whereas long, shallow, raceway type ponds are ideal for this purpose. Very often the type of pool selected depends on several factors, such as amount of water available, surrounding terrain, and accessibility. In fish culture as it is practiced today, ponds must lend themselves to ease in flush treatment for prevention of disease, automatic grading, accessibility to mechanical loading and feeding equipment, and simplicity in over-all management. In California, modified raceway ponds are in general use.

Rearing Pond Capacities

The carrying capacities of rearing ponds depend, to a large extent, on conditions existing at the various hatcheries. Capacities must be established at the hatchery itself to be of benefit in planning the station program. Some of the factors which influence or determine the carrying capacities of rearing ponds are: (1) water quality, (2) water temperature, (3) water volume, (4) rate of flow, (5) rate of change, (6) reuse of water, (7) degree of pollution of water supply, (8) kind of fish held,

(9) size of fish held, (10) frequency of grading and thinning, and (11) diseases encountered.

The best way to determine the proper holding capacities of rearing ponds at a particular installation is to examine the results of several seasons of production for which accurate records are available regarding numbers and weights of fish held, growth, food conversion, types of feed used, incidence of disease, and mortality—all plotted against the basic factors, such as water volume and temperature, which might influence holding capacities.

Circular Ponds

The advantages of the circular pond are: less water required; nearly a uniform pattern of water circulation throughout the pool, with fish more evenly distributed instead of congregating at the head end; center outlet, with circular motion of water producing a self-cleaning effect. Even though less water is required, sufficient head or pressure must be available to force and maintain the water in a circular motion. In operating a circular pond, advantage can be taken of an interesting phenomenon. Since the vortex of a whirlpool in the northern hemisphere always rotates in a counterclockwise direction, the water in a circular pond should also rotate in a counterclockwise direction.

To take advantage of the self-cleaning effect of the circular pond, it is necessary that the proper type screen and outlet pipe be used. In effect, the self-cleaning screen consists of a sleeve larger than the center outlet or standpipe. This sleeve fits over the outlet pipe and projects above the surface of the water. The sleeve may have a series of slots or perforations near the bottom which act as an outlet screen for small fish or may be in the form of a narrow opening between the pool bottom and the lower end of the sleeve for larger fish. This opening must be adjusted according to the size of the fish in the pool. Waste materials are drawn through the opening by the outflowing water.

While carrying capacities will vary among installations, circular tanks 14 feet in diameter, with a water depth of 30 inches and an inflow of 50 gallons per minute, will safely carry 400 pounds of trout at water temperatures up to 60 degrees. With a comparatively small amount of water used in a circular pool, the rate of water exchange is quite slow and extreme care must be taken in feeding. Every precaution must be taken to prevent the water from becoming seriously discolored by excess of food, with resulting oxygen depletion and loss of fish.

Circular ponds do not lend themselves well to flush treatment for disease control nor to mechanical fish-loading or self-grading devices. The advantages of the circular pond for yearling and larger trout are not as great as thought when circular ponds first began to appear, and the older type earthfill rearing pond remains the most popular. The circular pond, however, is well adapted to rearing trout ranging from newly-hatched fry to fish of subcatchable size.

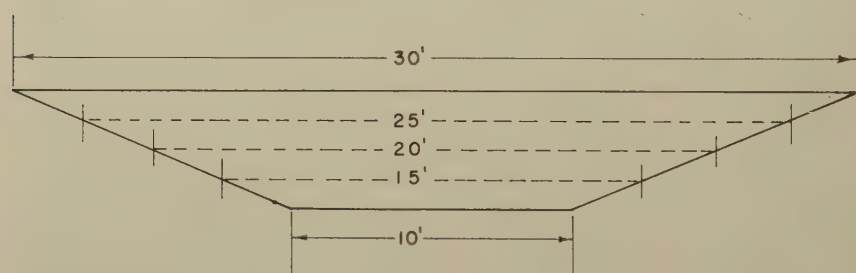
Raceway Ponds

The earthfill raceway type rearing pond, with concrete cross dam, is the most widely used pond at California hatcheries. Standard raceways are 100 feet long, 4 feet deep, 10 feet wide at the bottom and 30

feet wide at the top, and the sides slope $2\frac{1}{2}$ to 1. The gradient is 6 inches in 100 feet. There is a roadway along one side.

Raceways are usually installed in series from 4 to 8 ponds long. By allowing the water to drop at least 6 inches between ponds, it is possible to operate up to 8 ponds in a series on a water supply of 3 c.f.s., or approximately 1,345 gallons per minute, at temperatures not to exceed 65 degrees, and provided the water is not seriously discolored or polluted during feeding operations. In this respect, feeding a series of raceway ponds is greatly facilitated when floating feeding frames are used for frozen foods, or a blower-type feeder is employed when dry foods are used.

The standard California raceway pond has many advantages. It can be effectively flushed with chemical for disease control. Sloping sides provide considerable flexibility in pond management and access to the pond. When operated at a water depth of 36 inches, the pond has a water capacity of approximately 50,490 gallons, a surface area of 2,250 square feet, and the current is fairly slow. By reducing the water depth to 12 inches, the pond is converted to a virtual millrace, with a capacity of only 9,350 gallons and a surface area of 1,250 square feet (Figure 29). Dams between ponds are designed to make grading almost automatic by the installation of parallel-bar grading racks of the spacing desired.



Depth	Surface width	Surface area	Gallons
1 ft.	15 ft.	1250 sq.ft.	9,350
2 "	20 "	1750 " "	26,180
3 "	25 "	2250 " "	50,490
4 "	30 "	2750 " "	82,280

FIGURE 29. Surface area and capacity of standard California raceway pond.

Earthfill ponds, like natural streams, have a remarkable capacity for self-purification, making frequent cleaning unnecessary. The bottom accumulations support a luxuriant growth of small organisms, including bacteria, algae, protozoa, and insect larvae, which quickly cause their disintegration, so that the organic compounds are reduced to non-toxic, inorganic substances. The decaying matter contains larvae and these, with the algae present, add to the food available to the fish. It is believed by some fish culturists that this, to some extent, is responsible for better results obtained when fish are reared in natural, earthfill ponds, compared with concrete-lined ones.

AQUATIC VEGETATION IN PONDS

Aquatic vegetation can usually be divided into three general groups: algae (suspended and mossy filamentous), emergent vegetation (tules and cattails), and submergent vegetation (plants rooted to the bottom that do not extend above the water surface). All are a hindrance to fish removal, feeding, access, and general pond management. In raceway ponds with a fair current, aquatic vegetation other than algae normally does not become too bothersome. Raceway ponds do not lend themselves very well to weed eradication programs. In the deep, still-type pond, aquatic vegetation usually grows rather profusely, but control measures are more easily effected. Under certain conditions, plants regulate the amount of oxygen available to the fish in a pond and govern the number of fish which can be carried.

Photosynthesis

Photosynthesis is the process by which plants manufacture food. Plants that are able to carry on photosynthesis contain a green substance, chlorophyll. The sun furnishes the energy required for plants to produce certain chemical combinations. In the process, oxygen is freed and escapes from the tissues of the plant by diffusion. Thus, aquatic vegetation in fish ponds helps build up the oxygen content in the water during periods of sunlight and at such times may even be beneficial. The process, however, is reversible, and during periods of darkness or overcast days, when sunlight is absent, oxygen is taken from the water by plant growth. Oxygen depletion, due to overabundant plant growth, with resultant fish kill, is not uncommon.

Aquatic Vegetation Control

The task of controlling aquatic vegetation has been made considerably easier during the past few years by the development of new chemicals known as herbicides. The ideal herbicide should have the following qualifications: (1) it must destroy or depress aquatic vegetation at concentrations not lethal to fish or other desirable aquatic organisms, (2) it must not adversely alter the water or substrate as a desirable biological environment, (3) it must be dependable under a wide variety of physical and chemical conditions, (4) it must be safe to handle and apply, and (5) it must be economical to use.

Although a number of new and promising chemicals have appeared on the market in recent years, the ideal aquatic herbicide, as described above, has not been developed.

Some of the newer herbicides are:

Delrad 50 and 70—Chipman Chemical Company, P. O. Box 679, Palo Alto, California.

Karmex W—E. I. duPont de Nemours and Company, Information Center, 3051 Santa Monica Boulevard, Los Angeles, California.

Dalapon (Radapon, Dowpon)—Dow Chemical Company, Agricultural Chemical Sales Department, Midland, Michigan.

Aminotriazole—American Chemical and Paint Company, Agricultural Chemical Division, Niles, California.

Chem-Pels 2,4-D—Chemical Insecticide Corporation, 30 Whitman Avenue, Metuchen, New Jersey.

Estercide 4-D—California Spray-Chemical Company, 515 N. Tenth Street, Sacramento, California.

Silvex—Dow Chemical Company, Agricultural Chemical Sales Department, Midland, Michigan.

Other chemicals which have been effectively used for aquatic vegetation control are copper sulfate and sodium arsenite.

Most of these chemicals are poisonous to both fish and/or other animals when used above the recommended dosages. All materials containing sodium arsenite are particularly lethal to mammals, including man.

Algae: Recommended chemicals are copper sulfate, Karmex W, Delrad 50 and 70, and sodium arsenite.

Emergent vegetation: Recommended chemicals are Dalapon, Amino-triazole, and Estercide 4-D.

Submergent vegetation: Recommended chemicals are Karmex W, sodium arsenite, Chem-Pels 2,4-D, and Silvex.

Details on the use of most chemicals may be secured by writing the manufacturers. Even though effective chemicals are available, control of aquatic vegetation is quite complicated. Concentrations must be kept harmless to fish life, yet be strong enough to kill vegetation. Before attempting chemical control, one must determine the strength of solution usable without endangering the fish. Normally, warmwater fish can withstand higher concentrations than trout and salmon.

To apply the correct amount of chemical, after the concentration has been determined, it is necessary to determine the volume of water to be treated. The following formula should be used to compute the volume and amount of chemical required.

1. Determine volume of pond or reservoir in acre-feet:

$$\frac{\text{Length in feet} \times \text{width in feet}}{43,500} \times \text{average depth} = \text{number acre-feet.}$$

2. Multiply number of acre-feet by 0.3 to convert to millions of gallons.

3. Determine the amount of chemical to be used in pounds per million gallons.

4. Multiply pond volume (expressed in number of million gallons or fraction thereof) by pounds of chemical required for proper species.

Example: Pond 100 feet $\times$ 200 feet $\times$ 10 feet *average* depth contains trout.

- a. $\frac{100 \times 200}{43,500} \times 10 = \text{approximately } 5 \text{ acre-feet.}$

- b. $5 \text{ acre-feet} \times 0.3 = 1.5 \text{ million gallons.}$

- c. 10 pounds of chemical used per million gallons is tolerance for trout.

- d. $10 \times 1.5 = 15.0 \text{ pounds of chemical required for pond treatment.}$

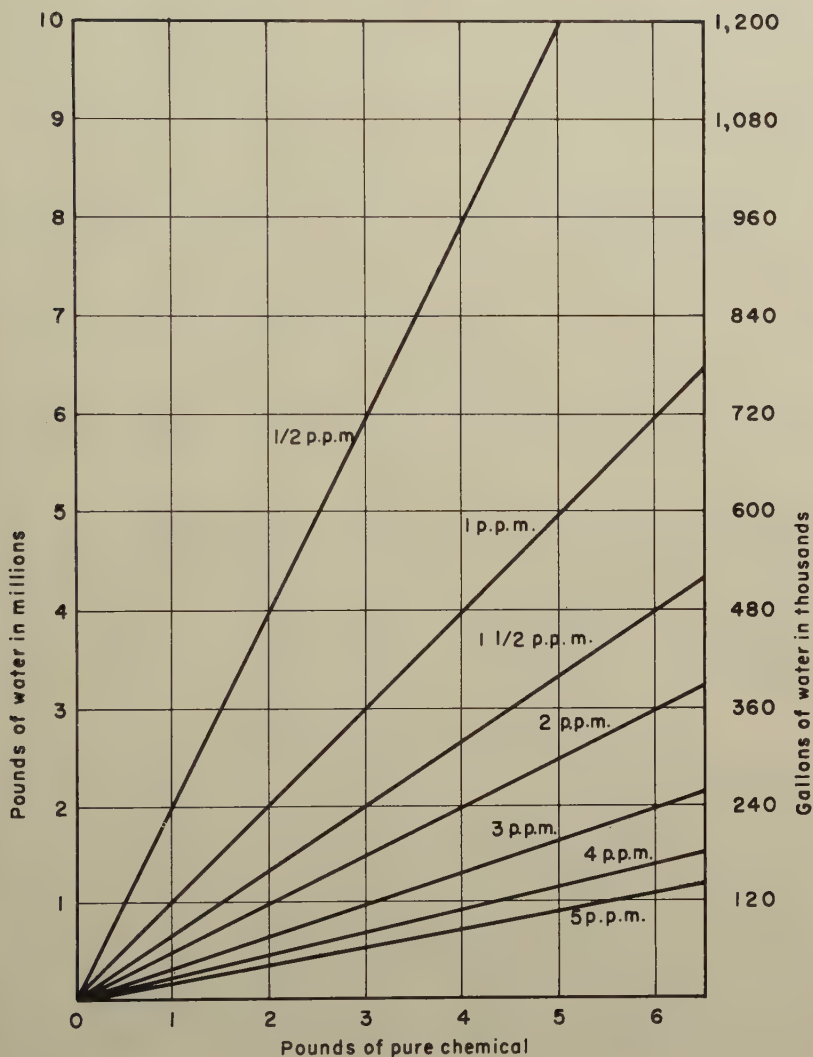


FIGURE 30. Concentration chart.

Normal tolerance to various herbicides for trout and warmwater fish is as follows:

	Concentration in p.p.m.	
	Salmonids	Centrarchids
Copper sulfate	0.1	1.0
Delrad 50 and 70	0.5	1.0
Karmex W	1.0	5.0
Dalapon	*	*
Aminotriazole	*	*
Sodium arsenite	4.0	7.0
Silvex	*	*

* Not fully determined.

Chem-Pels 2,4-D has been used effectively as a "spot" treatment for submergents at the rate of two pounds per 1,000 square feet of weeds, without loss of trout, largemouth bass (*Micropterus salmoides*), or bluegill (*Lepomis macrochirus*).

The strength of solution to be used can best be determined by contacting the company supplying the chemical.

The effectiveness of most herbicides is highly variable and is dependent on temperature and alkalinity of the water and density of the aquatic growths. Toxicity to fish is likewise affected. Before large-scale control measures are put into effect, it is well to experiment on a small scale with the chemical to be used and determine the concentration which will most satisfactorily do the job at the particular location.

Treat plants (except tules and cattails) preferably while they are young, tender, and growing rapidly. Do not wait until they become a nuisance, since then it may be too late for effective control and a great deal of time and expense may produce no more than moderate success. There is also the danger of oxygen depletion, caused by decaying vegetation, when luxuriant plant growth is killed. Treatment of tules and cattails should take place when plants are mature, since success of spraying is proportional to the leaf area contacted by the chemical.

In using herbicides, the user is cautioned against the danger of destroying valuable plants nearby through air drift. This is particularly true in the case of chemicals which are applied by surface spraying.

TROUT AND SALMON NUTRITION

Almost no phase of fish culture is more important than nutrition and feeding. For many years, it was quite generally assumed that beef liver was a complete diet for trout, and beef liver was fed in trout hatcheries in greater amounts than any other food. Fortunately, rather large amounts of condemned livers (livers condemned because of fluke infestation), which kept the price within a reasonable range, were available to hatcheries situated west of the Rocky Mountains.

As larger trout were produced, it became evident that beef liver, while it was one of the best trout feeds available, was not a complete trout food and it became common practice to supplement a liver diet with other packing-house products, such as lungs, hearts, and spleens. Early fish culturists in this country suspended freshly killed beef heads over their ponds. After a few days maggots would fall from the heads into the ponds. This is probably one of the earliest attempts to provide a natural food for hatchery fish. Such products as ground whole fish, both ocean and freshwater varieties, fish cannery by-products, and numerous cereals were also used to supplement hatchery diets of packinghouse products. These are fed on a rather extensive scale today.

The nutritional requirements of trout and salmon are not yet fully determined. Fish nutrition, when compared to that of other domestic animals, is still in its infancy. Obvious reasons for this are the lack of work in this field and the difficulty of working with fish. The amount of research in trout nutrition is constantly increasing. In future years

the trout production industry may be abreast of other fields in nutritional knowledge. In the meantime, many of the requirements of trout are based on the dietary needs of other animals. In general, this is a safe assumption. However, fish are cold-blooded animals, their body being of the same temperature as the water surrounding them, and their ability to assimilate food under varying conditions must be taken into account.

The intestinal tract of a trout is that of a typical carnivore. Both small and large intestines are very short, and the total length of the digestive system is not great enough to allow any important synthesis of vitamins by bacteria in the intestines. Most of these requirements must be supplied in a digestible form in the food.

Realization of these shortcomings in a trout's digestive system is a long stride forward in understanding its food requirements.

Present nutritional knowledge has been built around five principal groups of nutrients. They are fats, carbohydrates, proteins, minerals, and vitamins.

Fats

The three sources of fat used to meet bodily requirements are fat of the diet, fat produced by excess dietary protein, and fat produced by excess carbohydrates.

Most dietary fat is changed to fatty acids and glycerol in the small intestine before absorption. The ease of this process is primarily dependent on the melting point of the fat. Soft fats are easier to digest than very hard fats. Digestibility varies from 70 to 90 percent, depending on the melting point and body temperature.

Hard fats may retard or prevent the digestion of protein and carbohydrates by coating their molecules. This insulates them from the action of the protein- and carbohydrate-digesting enzymes and acids. Small trout have special difficulty in digesting hard fat. It is believed that hard fats also lessen a trout's ability to adjust to water temperature changes.

The body uses fats for energy, insulation, and cushioning of vital organs, and as an internal lubricant. They are also stored for future use.

Fats aid in the absorption of the fat-soluble vitamins, which are necessary for normal health and growth. Phospholipides are kinds of fat which contain phosphorus, fatty acids, and choline, or other important bases.

There are two types of fat deposits in the body: one is the natural fat of the animal manufactured from the protein and carbohydrate of the diet; the other is deposited from fat in the diet. Fat deposited from dietary fat is similar to that of the original food. Excessive fat deposits may be caused either by overfeeding or by high fat content of the food.

Excessive dietary fat can cause body damage resulting in death. Important food conversions take place in the liver; fatty infiltration of the liver may cause anemia resulting in the death of the fish. Kidneys damaged by excessive fat deposits may result in edema, i.e., an accumulation of water in the body.

The principal sources of fats are fish meal and oil, cottonseed meal, rice bran, fresh fish and meat, and meat and bone scrap.

Cod liver oil has been found to increase growth under certain conditions, but it is not clear whether this effect is caused by the lipides themselves or the vitamin A and D present in the oil. Due to possible kidney and liver damage, caution should be used in feeding cod liver oil in cold water. Oxidation of fish oils such as cod liver oil, when mixed into the diet, will cause destruction of vitamin E.

Insofar as is now known, the trout diet should contain not less than 5 percent and not more than 8 percent fat.

Minerals

Minerals are generally considered important in building strong bones. The important part they play in the functional activities of the body is not widely appreciated. Blood circulation, respiration, digestion, and food assimilation, as well as excretion, are dependent on the presence of minerals in suitable compounds. The minerals important in trout and salmon nutrition are listed in Table 8.

TABLE 8
Important Nutritional Minerals

Major	Use	Trace	Use
Calcium-----	Bones, teeth, blood coagulant	Cobalt-----	Red blood cells
Phosphorus-----	Bones, teeth-----	Iron-----	Red blood cells
		Copper-----	Red blood cells; enhances enzyme action
		Magnesium---	Bones, teeth
		Sodium-----	Osmotic cell pressure
		Chlorine-----	Osmotic cell pressure, digestion
		Potassium---	Osmotic cell pressure
		Manganese---	Growth
		Fluorine-----	Teeth, bones
		Iodine-----	Regulates metabolism

Usually minerals are needed in only small amounts. While calcium, phosphorus, and iron are used in building the body and blood, most of the minerals function as catalysts.

Trout have the ability to absorb calcium, cobalt, and phosphorus from the water. Enough for bodily needs may be absorbed if there is enough present in the proper form. The amount absorbed from the water varies in proportion to the amount in the water.

Calcium and phosphorus in the ratio of 2 to 1, respectively, are the major minerals used in forming the bones and teeth. Fluorine and magnesium are trace minerals involved in the structure of the body.

Iron, cobalt, and copper are trace minerals used to build red blood cells. Iron and cobalt are combined in the red blood cells. Copper acts as a catalyst to aid in the assimilation of iron. A deficiency of any one will cause anemia.

Sodium, chlorine, and potassium regulate the osmotic pressure of the body cells. Body fluids contain about 90 percent of the body content of these minerals.

Minerals involved in the special body processes act as catalysts and, with the exception of calcium and phosphorus, are considered to be trace minerals. Chlorine aids digestion, copper increases enzymatic action, iodine helps regulate metabolism, and calcium is a blood-coagulating agent.

To illustrate the limited knowledge of trout nutrition, only iodine has been proven to be essential and only salt has been found to be harmful when fed in excessive amounts.

Fish, bone, kelp, and meat meals; dried skim milk; fresh meats; and fish are good mineral sources.

Vitamins

The understanding of vitamins has increased rapidly in the last few years. There are now 16 generally recognized vitamins. Probably there are more to be discovered. The known vitamins, their requirements, and known symptoms of deficiencies are listed in Table 9.

TABLE 9

Vitamins

Vitamins	Minimum daily requirement in mg. per kg. body weight	Deficiency symptoms
Fat soluble		
A.....	Unknown.....	Unknown. Believed to cause cataracts, retarded growth.
D.....	Unknown.....	Unknown.
E.....	Unknown.....	Unknown.
K.....	Unknown.....	Unknown.
Water soluble		
B ¹ thiamin.....	0.150.....	Mortality from shock and fright; poor appetite; instability; convulsions; pale livers.
B ² riboflavin.....	0.44-0.68.....	Blindness; hemorrhagic eyes, nose, and operculum.
Pantothenic acid.....	0.97-1.25.....	Western gill disease.
Pyroxine.....	0.225-0.250.....	Nervous disorders; light spots on the liver.
Inositol.....	Unknown.....	Poor growth; distended stomach; degenerated fins.
Biotin.....	0.0433-0.00678.....	Anemia; poor growth; blue slime.
Folic acid.....	0.00292.....	Anemia; poor growth.
Niacin.....	3.0-4.0.....	Swollen, unclubbed gills; poor growth; back peel.
Ascorbic acid-C.....	Unknown.....	Hemorrhagic liver, kidney, and intestine (suspected).
Vitamin B ¹²	Unknown.....	Unknown. Probably not required.
Para-aminobenzoic acid.....	Unknown.....	Unknown. Probably not required.
Choline.....	Unknown.....	Hemorrhagic liver, kidney, and intestines; fatty infiltration of the liver.

Some vitamins are found in more than one form, notably A and D. Each vitamin performs functions not wholly duplicated by any other, yet the actions are interrelated.

It is known that only minute amounts are needed and that they act as catalysts, making it possible for the body to utilize the other diet components.

Vitamins are classified as fat-soluble and water-soluble. In general, fat-soluble vitamins can be stored in the body and water-soluble vitamins cannot.

Of the 16 known vitamins, 10 are known to be essential to trout. However, until further work is done, it should be assumed that all vitamins are essential.

It is generally conceded that unknown diseases and unusual severity of bacterial diseases may be caused by vitamin deficiencies. Other than their effect on the general condition of the fish, they are not believed to have any effect on virus diseases.

To add to the hatchery managers' problems, only 4 of the 10 essential vitamins have definite external deficiency symptoms. Symptoms of the others are shown by retarded growth rate and internal damage. There is considerable overlapping of symptoms.

Proteins

The main component of the body organs, soft tissues, and body fluids is protein. Blood meal, for instance, contains 85 percent protein. Beef liver meal contains 66 percent protein.

Proteins are made up of amino acids, which consist of carbon, hydrogen, oxygen, and nitrogen. The nitrogen level is fairly constant at 16 percent. The amino acids are present in widely varying amounts in different proteins. As shown in Table 10, 18 amino acids have been identified. Ten of these are probably essential in trout food. The other eight may be manufactured in the body, or are not required.

TABLE 10
Known Amino Acids

Essential	Other
1. Arginine.....	1. Tyrosine
2. Histidine.....	2. Glycine
3. Isoleucine.....	3. Alanine
4. Leucine.....	4. Aspartic acid
5. Lysine.....	5. Cystine
6. Methionine.....	6. Glutamic acid
7. Phenylalanine.....	7. Proline
8. Threonine.....	8. Serine
9. Tryptophan	
10. Valine	

The term biological value of a protein indicates the degree of digestion and amino acid balance of a protein. The more nearly a protein resembles the protein found in the body of the animal being fed, the more it is utilized.

Digestion splits proteins into amino acids. The acids then pass through the intestinal wall into the blood stream. They are then carried to the liver and to other body cells, where they are reformed into proteins of various kinds.

Proteins are used primarily for growth. Excess protein may be used for energy or deposited as fat. In most animals, fats and carbohydrates are used for energy. However, if the diet is low in these, protein will be used to supply energy.

No amino acids are stored in the body. They must be supplied in the proper balance each day and they should all be fed at the same time.

While not fully understood, the amino acid content of proteins is known to be damaged by high temperature. It is also known that protein content may be lost by leaching.

Twenty-eight percent is believed to be the desirable level of protein in the trout diet. There is some evidence that a diet containing 50 percent protein may be fed to advantage.

Protein deficiency symptoms are even more indefinite than vitamin deficiency symptoms. However, they occur much more quickly. The only protein deficiency symptoms which have been described are lack of appetite, reduced activity and growth, and fish staying near the top of the water.

Animal concentrates, fresh meat, and fish are excellent sources of protein. Plant concentrates, especially seeds and grains, are also good sources of protein, although their use is complicated by their high carbohydrate content and their amino acid patterns.

Carbohydrates

Carbohydrates are made up of hydrogen, carbon, and oxygen. Unlike proteins, they do not contain nitrogen. They are used as energy, temporarily stored as glycogen (animal starch), or formed into fat.

Compound carbohydrates are digested into simple sugars before they are absorbed. Their availability is dependent on a fish's ability to digest them.

Carbohydrates in the body are found in the form of glucose (sugar) and glycogen. Glucose is deposited in the fluids and cells of the body, and glycogen in the liver and muscle tissues.

Excess carbohydrates in the diet will cause swollen bodies and deposit excess glycogen in the liver, resulting in swollen, light-colored livers. Mortality will be high.

Not over 9 to 12 percent of digestible carbohydrate should be included in a diet for salmonids. Practically all trout and salmon diets containing dry food exceed this percentage of raw carbohydrates. This is possible because all of the carbohydrates are not digested. Often only a small part is available to the fish. For example, only a minute fraction of the carbohydrate content of distillers' solubles is digested.

In general, the more complex the carbohydrate, the harder it is to digest. However, cooking makes carbohydrates more digestible. A satisfactory diet may be ruined by cooking simply because the carbohydrates become more digestible.

Major sources of carbohydrates are plant products. Meats contain only minor amounts of carbohydrates.

Interrelationships

Up to this point, nutrition does not sound too complicated; one feeds a diet containing the right amount of fats, minerals, carbohydrates, and vitamins; if a deficiency appears, the lacking component is added and the deficiency is corrected.

To some extent, this is true. However, a great many interrelationships between vitamins, between minerals, and between amino acids, as well as between members of these groups and of other groups, such as

proteins, fats, and carbohydrates, have been discovered. Sometimes the interrelationship hinges on the intervention of a third factor. Some interrelationships affect the synthesis of vitamins, others the preservation, destruction, or functioning of vitamins.

One example is the relationship between vitamin D, calcium, and phosphorus. All are needed to build strong bones. Vitamin D's function is to prevent rickets. However, if there is not enough calcium or phosphorus in the diet or if they are not in the proper proportion, vitamin D cannot prevent rickets. An excess of calcium will increase the demand for vitamin D until a level is reached at which it is impossible to supply enough to prevent rickets.

Some materials act as inhibitors. Linseed oil meal may cause a pyridoxine deficiency even though the diet contains a high level of pyridoxine.

A shortage of any essential amino acid will limit the effectiveness of the others present to the level of the lowest one. The same is believed to be true of vitamins. Excess of some diet factors may cause an imbalance which will cause the whole diet to fail.

The synthesis of the B group of vitamins and amino acids in trout is probably negligible. Synthesis of these groups depends on intestinal bacteria, which are not believed to be important in the intestines of trout.

All of this leads to the conclusion that it is not so much what the diet contains that is important, but what it accomplishes in the body. Nutrients are rarely completely digested and frequently the digested fraction of the nutrient is not completely utilized.

FOOD STORAGE AND PREPARATION

The best foods available may lose their value through improper storage and preparation. Millions of dollars worth of synthetic vitamins, purchased annually by consumers, are lost before feeding. Microorganisms, enzymatic action, and oxidation, encouraged by unfavorable conditions, contribute to the destruction of the nutrients contained in foods.

The action of bacteria, yeasts, and molds causes spoilage and deterioration. These microorganisms utilize the soluble constituents of the food or secrete enzymes which cause decomposition.

Enzymatic action results in a process known as autolysis. Autolysis resembles digestion, except that digestion is carried out by enzymes in the tissues of living material. In dead tissue the action continues and results in tissue disintegration.

Proteins, fats, and vitamins are the nutrients most subject to destruction in storage and preparation. These are also the most important items in a diet for salmonids.

Proteins are subject to destruction by microorganisms, autolysis, and heat. Microorganisms and autolysis cause decomposition, leading to alteration or destruction of the protein content of the food. High temperature alters the protein content, reducing the biological value of the protein.

Fats are altered or destroyed by autolysis and oxidation. Autolysis increases the acidity of fats. Rancidity, resulting from oxidation, can make fats indigestible and may produce fatal toxins. Vitamins A, C,



FIGURE 31. Feed room at Mt. Shasta Hatchery, 1914. Diet consisted of ground beef liver, clabbered milk, and cooked wheat middlings. Bags in foreground contain wheat middlings.

and E are destroyed by oxidation. In addition to destruction by oxygen, microorganisms, and autolysis, vitamins may be unfavorably affected by light, heat, and moisture.

Freezing and drying are the principal methods employed for the preservation of fish foods. Refrigeration is the most satisfactory method of preserving raw animal products. Autolysis and the action of microorganisms are inhibited by cold temperature. The degree of coldness has a direct bearing on the speed of these processes.

Meats and fish should be quick-frozen at -35 degrees and stored at -10 degrees. At this temperature, autolysis is minimized and oxidation is greatly reduced. Deterioration does continue, however, and considerable value may be lost after 90 days in storage.

Figure 32 shows the results of three different retention times before freezing and the effects of different storage temperatures on the quality of fish.

The upper curves show a 15 percent quality loss due to freezing when frozen immediately after taking. The rate of deterioration to zero quality is shown as 12 months at -20 degrees temperature, increasing to 6 months at 0 degrees storage temperature.

The middle curves indicate the quality relationship when fish are held on ice for one week prior to being frozen. These will enter the freezer with a quality score of $66\frac{2}{3}$ percent, leave in the frozen state at $50\frac{2}{3}$ percent, and exhibit a considerably shortened storage life. The lower four curves indicate the doubtful practicability of freezing fish that have been held two weeks on ice.

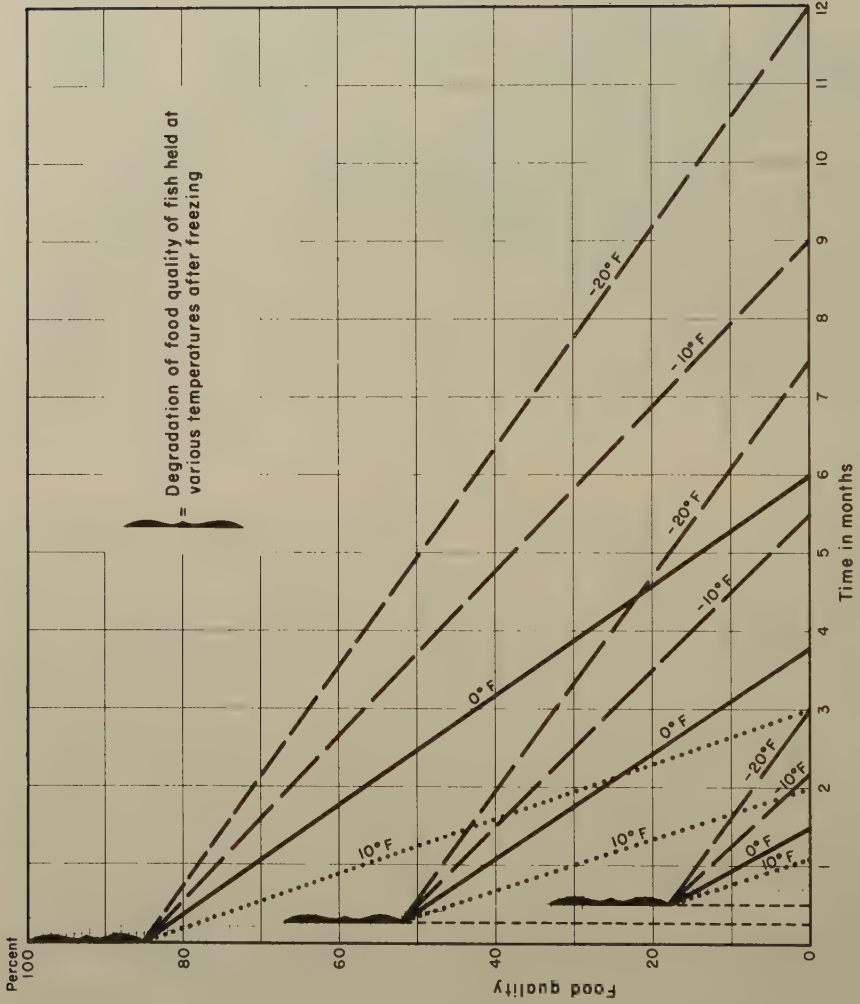


FIGURE 32. Degradation of food quality of fish held at various temperatures after freezing.

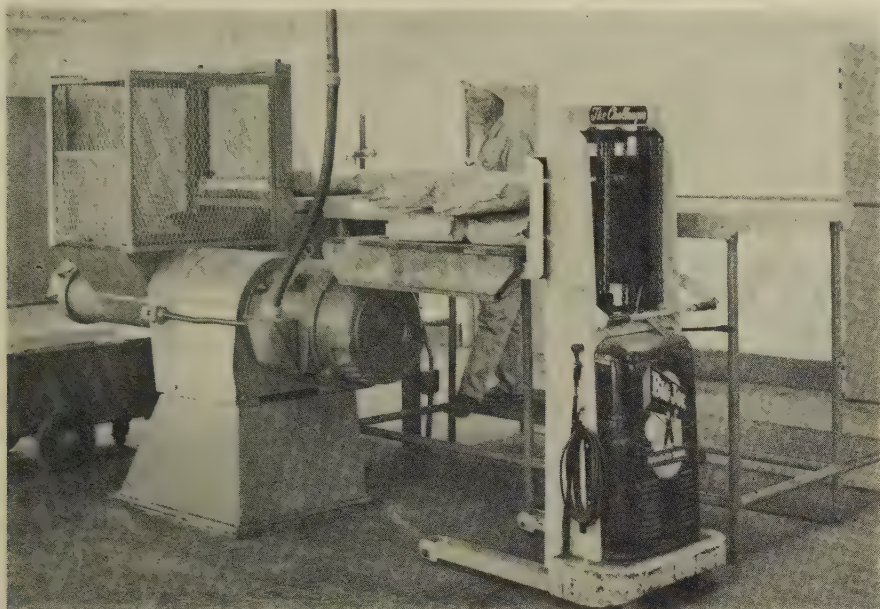


FIGURE 33. Modern hatchery food preparation room with refrigerated storage and ice-making equipment. Frozen food sliced by hydraulic slicing machine falls directly into food grinder. Photograph by Harold Wolf, July, 1958.

The manner in which animal products are handled prior to freezing is of great importance, if the maximum value is to be preserved. The protein quality and vitamin content of meat products which have been allowed to decompose partially before freezing are reduced. Fish products in which decomposition has occurred before freezing may prove to be toxic.

Thawing and refreezing results in reduction of the vitamin content, due to rupture of cell walls. Slow thawing is responsible for a high loss of water-soluble vitamins. Prolonged retention of any ground product after thawing results in reduced food value. No more food should be ground or thawed at the hatchery than can be used in 48 hours. To prevent excessive loss of diet value, ground meat and fish products should be stored after thawing at as cold a temperature as possible without fusion of the particles by freezing. Usually, 30 degrees F. is satisfactory.

The conversion of raw products to meals by the application of heat is used extensively. Dehydration by heat stops autolysis, but accelerates oxidation. The proteins may be altered by high temperatures. Some of the vitamins are destroyed by heat. Precooking before dehydration causes a loss of the water-soluble vitamins. Low temperature dehydration processes have been developed. It is desirable to use meals processed by this method in dry food formulas.

Once a product has been reduced to meal, the vitamin content is relatively stable. However, when various meals are mixed together, some of this stability is believed to be lost. Dry food should be stored in a cool, dry place until used. It should not be stored longer than 60 days.

Meat and fish diets, once prepared, cannot be stored unfrozen without important losses of essential food nutrients. Although cold storage inhibits autolysis and oxidation, these processes resume at an accelerated rate as soon as the temperature is allowed to rise.

Ground meat and fish mixed together should be used within 24 hours. Fish often destroy the thiamin content of the meat when mixed with it.

HATCHERY DIET INGREDIENTS

The ingredients of a trout diet must be available in sufficient quantities to supply the demand and produce good growth with a minimum mortality. No single component is as satisfactory as a combination because no single component contains all the nutritional requirements of trout and salmon.

Hatchery diets are usually composed of a combination of meats and fish or meals of both animal and vegetable origin. Both fresh meats and animal meals are higher in protein content and in biological value of the protein than vegetable meals. While successful dry food diets have been devised, no diet has been made without inclusion of products of animal origin.

Table 11 shows the analysis of some of the more commonly used trout and salmon foods. In general, meats used for fish food are limited to those which are not used extensively for human consumption, either because they are unfit or unsuitable.

Meat products may be divided into organs such as liver and spleen, and muscle meats such as heart and flesh. The organs have a higher vitamin and protein content than muscles.

Beef liver is one of the most commonly used foods for trout and salmon. It has a high vitamin content and consists of about 2.5 percent carbohydrate, 3 percent hard fat, 20 percent protein, and 72 percent moisture. It is not a complete food because of the low biological value of the protein. However, its high vitamin content makes it an excellent supplement.

Hog liver has about the same protein, fat, and mineral content as beef liver. The carbohydrate content is even lower. The biological value of the protein is comparable to beef liver. Superior growth and health have been demonstrated when the two foods are combined, as compared with results when either is fed alone. This indicates that the amino acid contents of their protein complement one another. Poor results are usually achieved with hog liver alone, probably due to loss of water-soluble components.

The protein, fat, carbohydrate, and mineral content of horse liver resembles that of beef liver. Vitamin content may be even higher. However, it is not available in worthwhile quantities.

Sheep liver contains 9 percent fat, 5 percent carbohydrate, and 23 percent protein. Vitamin content is lower than in other livers. When fed alone, it has been known to cause mortality due to excessive fat and glycogen deposits.

Beef spleen contains 18 percent protein and 2 percent fat. The protein does not have as high a biological value as beef liver and the vitamin content is lower. It is a good binder when mixed with other products.

TABLE 11

Analysis of Some Hatchery Foods

Food	Percent protein	Percent fat	Percent carbohydrate	Percent water	Percent ash	Percent fiber
Fresh meats						
Heart						
Beef	14.8	24.7	0.9	53.2	0.9	----
Sheep	16.9	12.6	----	69.5	0.9	----
Pig	14.4	2.9	----	79.5	----	----
Kidney						
Beef	13.7	1.9	0.4	74.0	1.0	----
Sheep	15.3	4.1	----	77.9	----	----
Pig	15.5	4.8	0.7	75.0	1.2	----
Liver						
Beef	20.2	3.1	2.5	72.3	1.3	----
Sheep	23.1	9.0	5.0	61.2	1.7	----
Pig	21.3	4.5	1.4	72.8	1.4	----
Horse	20.0	3.0	2.5	----	1.3	----
Lung						
Beef	16.4	2.8	----	79.7	1.0	----
Sheep	20.2	2.8	----	75.9	1.2	----
Muscle						
Horse	19.3	5.5	----	73.6	----	----
Beef	20.0	7.0	----	65.3	----	----
Tripe						
Beef	11.7	1.2	----	86.5	0.3	0.3
Spleen						
Beef	18.0	2.3	----	75.2	1.4	----
Pig	17.0	1.9	----	78.0	1.4	----
Viscera						
Horse	19.8	1.2	----	77.0	1.1	----
Fresh fish						
Alewives	10.0	2.4	----	----	0.8	----
Carp	10.0	15.0	----	----	0.5	----
Herring (sea)	11.2	3.9	----	----	1.6	----
Mackerel	10.0	4.2	----	----	0.7	----
Salmon	15.3	8.9	----	----	----	----
Shad	9.4	4.8	----	----	0.7	----
Smelt (sea)	18.7	1.3	----	----	----	----
Whiting	18.8	4.0	----	71.0	5.4	1.7
Canned fish						
Mackerel	19.6	8.7	----	----	1.3	----
Salmon	19.5	7.5	----	----	----	----
Shrimp	25.4	1.0	0.2	----	2.6	----
Animal meal						
Blood	82.2	1.2	0.7	----	3.3	0.6
Buttermilk	33.8	5.6	41.9	7.8	10.5	0.3
Bone	7.1	3.3	3.9	----	81.3	0.8
Liver	67.2	14.6	2.4	----	7.5	1.9
Meat	55.0	12.0	1.2	----	25.0	2.2
Meat crisp	75.0	----	----	9.7	----	----
Skim milk	34.8	0.9	50.1	6.2	8.0	----
Whey	12.5	0.7	72.1	----	9.7	----
Fish meal						
Crab	36.5	2.9	7.4	----	39.5	5.7
Dog fish	76.3	8.4	----	11.0	11.1	----
Herring	72.6	----	----	----	----	----
Menhaden	61.0	7.0	0.8	----	21.0	2.4
Salmon	55.4	----	----	----	----	----
Salmon egg	39.3	8.7	----	9.3	10.7	----
Salmon viscera (pink)	59.6	17.0	----	5.7	11.3	----
Salmon viscera (red)	60.1	24.3	----	5.7	----	----
Shrimp	42.1	2.2	1.4	----	33.8	9.3
Sardine	64.5	9.8	3.8	----	15.2	0.2
White fish	54.5	8.8	4.6	10.5	22.0	1.0

TABLE 11—Continued
Analysis of Some Hatchery Foods

Food	Percent protein	Percent fat	Percent carbo- hydrate	Percent water	Percent ash	Percent fiber
Plant meal						
Apple pumace.....	4.5	5.0	62.1	----	2.2	15.6
Beet pulp.....	9.0	0.8	59.9	----	3.5	18.8
Bran.....	16.0	4.4	63.2	----	6.3	9.5
Corn gluten.....	26.4	2.5	48.4	----	6.1	7.1
Cottonseed.....	38.0	8.0	39.9	----	6.4	10.5
Kelp.....	5.6	0.7	43.7	----	33.2	7.5
Oat flour.....	15.0	5.8	66.7	----	1.9	2.6
Oatmeal.....	16.0	6.5	67.6	----	2.0	2.8
Peanut.....	44.8	10.2	33.6	----	4.8	18.9
Red dog flour.....	16.8	4.1	65.5	----	2.5	2.4
Rice bran.....	12.8	13.4	41.1	----	10.8	13.0
Soy bean (expeller).....	49.9	6.2	26.4	----	5.5	5.1
Soy bean (solvent).....	46.4	1.6	31.7	----	6.0	5.9
Wheat middlings.....	17.8	5.0	62.8	----	3.7	4.4
Wheat shorts.....	17.4	4.9	62.8	----	4.4	6.2

Beef heart has been used as a starting food for fry. It contains about 16 percent protein and 20 percent fat. The biological value of both its protein and vitamin content is low. This is to be expected, since it is a muscle meat. Its popularity as a fry food was partly due to its grinding consistency, food choppers being able to chop it into small individual particles rather than crushing it into a paste-like mass.

Horse meat has been used extensively in trout diets. It contains about 20 percent protein and 7 percent fat. It is a muscle meat high in connective tissues. The biological value of the protein is poor in contrast with other meat foods.

Other meat products such as lungs, tripe, and blood have been used extensively. These products have a low protein quality and low vitamin content. Usually they are available in fairly large quantities and may be used to supplement other diet ingredients, particularly fresh fish products.

Both freshwater and ocean fish have been used to supplement meat diets, with excellent results. As high as 80 percent frozen anchovies, supplemented with 20 percent beef liver, have been successfully fed to rainbow trout in California hatcheries.

Some fish products contain thiamanase, which removes the thiamin content of meat products. This can be prevented by feeding meat and fish products separately or by feeding immediately after mixing. Cooking destroys the thiamanase properties of fish, although it is usually considered impractical.

Salmon products such as viscera, offal, trimmings, and spawned-out carcasses have been used extensively as a diet supplement, particularly in northwest salmon hatcheries. Of these products, salmon viscera have proven to be the most valuable. They contain 20 percent protein and 4 percent fat. The vitamin B complex content is considerably lower than in beef liver. The protein has an excellent biological value. However, salmon products in the diet are suspected of being responsible for widespread outbreaks of kidney disease, fish tuberculosis, and sockeye

salmon virus disease. Therefore, use of these products should be viewed with caution.

Tuna viscera, minus the liver, are considered an unsatisfactory food. Their protein quality and vitamin content are low. U. S. Fish and Wildlife Service experiments have shown that slow growth and anemia result.

Hake and rock cod have a protein content of about 20 percent. The protein quality is good, producing excellent growth when used with a beef liver supplement. Some rockfish are low in protein. The growth rate of trout and salmon on a diet of rockfish is generally slow.

Anchovies contain 16.1 percent protein, 0.5 percent carbohydrate, and 3.5 percent fat. The vitamin content is below that of beef liver. The biological value of the protein is excellent. Excellent growth is achieved when anchovies are fed as a supplement to beef liver.

Carp have been used as a trout diet in midwestern and Rocky Mountain hatcheries. They should not be fed unless cooked. Excessive mortality in one California commercial trout hatchery was traced to a diet of raw carp that were approaching the spawning period.

In California hatcheries, frozen and fresh fish used as trout and salmon food are restricted to rock cod and anchovies. Several species of freshwater and ocean fish, other than the ones described here, have been used in other states. Whitefish, smelt, and herring meals are often used in dry formulated feeds.

Dry meals are used extensively in both trout and salmon rations. They have been used as a supplement mixed with meats and more recently as a complete ration in pelletized form. In some cases, the use of dry meals has resulted in excessive losses.

Vegetable products are considered inferior to animal products as sources of protein. They contain relatively high levels of more-or-less digestible carbohydrates and must be fed with caution. Cereal meals are high in B complex vitamins and are good sources of protein and minerals.

Dried skim milk, liver meal, and crab meal are high in vitamin content.

The method by which a meal is prepared, with special emphasis on temperature, affects its efficiency. Meals dried at temperatures below 145 degrees F. produce better results than flame-dried meals. High temperatures reduce the biological value of the protein by alteration. High temperatures also reduce the vitamin content.

Complete dry food trout rations are a mixture of meat, fish, and vegetable meals, usually with minerals and purified vitamins added. Great care must be exercised in balancing the amino acid and vitamin content. Properly balanced, the dry food diet will produce healthy, fast-growing fish. Not only is it necessary to have the right combination of meals, but the quality of the meals must be carefully controlled. Only tested brands of commercially prepared dry foods are used in California hatcheries. This, in effect, shifts the responsibility for quality control to the manufacturer. No dry food is purchased until it has undergone rigid performance tests.

Some of the more common ingredients of complete dry food diets are dried skim milk; herring, whitefish, blood, liver, soybean, and cottonseed meals; wheat middlings; and other vegetable products.

Spray-processed dried skim milk contains 37 percent protein, 1 percent fat, and 49 percent carbohydrate. All three are in a readily absorbent form for trout and salmon. The mineral and vitamin content is extremely high. The high digestible carbohydrate content limits the amount which can be used.

Whitefish meal from the offal of cod, haddock, and other white-meated fish contains about 68 percent protein and 2 percent fat. The mineral content and the biological value of the protein are high.

Other species of fish meal have also been used. Fish that have a high oil content do not produce good meals because of the tendency of the fat to turn rancid in storage.

Blood meal and meat meal have a high protein content of low biological value. They are used to supplement the protein value of other ingredients.

Vegetable meals are usually not mechanically dried, but are either ground or cooked. Although their protein quality does not equal that of animal meals, they are included to cheapen the diet and supplement the amino acid content of the other ingredients. Usually, they are high in vitamin B content.

Both cottonseed and soybean meals have relatively high protein content, 38 percent for cottonseed and 44 percent for soybean. Cottonseed meal is higher in fat and carbohydrates than soybean meal.

Wheat middlings contain about 17 percent protein and 63 percent carbohydrate, but are rich in B complex vitamins. The carbohydrates are of complex structure and are relatively indigestible by trout and salmon.

Other vegetable products are used as mineral and vitamin supplements. For example, kelp meal is particularly high in iodine content.

The choice of foods supplied to California trout hatcheries is limited by availability and price. The initial price of each product is important; however, the price per pound of fish produced on the food is usually the deciding factor.

FEEDING PRACTICES

The primary objective in feeding fish is to feed them adequately with a minimum of waste and the least amount of labor. Fortunately, the feeding habits of salmonids are readily adaptable to large-scale feeding practices.

Waste may be reduced and good growth and health maintained by careful attention to food preparation, size and type of food used, frequency of feeding, and close compliance with accepted feeding charts.

Grinding of meat and fish products is accomplished by a crushing as well as a cutting action. The crushing action breaks down the cell walls and makes the food more subject to the leaching action of water. To reduce leaching, grinding should be only sufficient to produce the proper size particles. Grinding the food while frozen will reduce the crushing action.

The food particles should be small enough to be eaten readily, yet prevent excessive loss through leaching. Particles too large to be broken down by the fish are completely wasted and may even cause death by choking.

The frequency with which fish are fed is governed by the size of the fish and the rapidity with which they clean up the food. When starting fish to feed, it is necessary that small particles of food be available for them to eat. To accomplish this, without the loss of water-soluble components, it is necessary to feed small amounts frequently. As the fish grow, they feed more vigorously and larger amounts of food may be fed at longer intervals.

The amount of food consumed daily is governed by the size of the fish, water temperature, and species. To secure the most efficient food utilization, fish should be fed amounts of meat and fish products slightly less than they will consume. The amount of dry food should also be considerably less than they will consume.

The growth rate may be increased by feeding all they will eat, but the increased gain rarely compensates for the additional food used. Fish fed all they can eat tend to become sluggish. They do not consume their food quickly and some of the nutrients are lost in the water. Underfeeding results in reduced growth rate and lowered disease resistance. Underfed fish usually have inadequate nutritional reserves to meet unfavorable conditions.

Feeding charts for both dry food and meat products have been developed. Table 12 shows the amount of meat and fish products to be

TABLE 12

The Recommended Amount of Wet Food to Feed Rainbow Trout Per Day in Percentage of Body Weight, for Different Size Groups Held in Water of Different Temperatures *

Water temperature in degrees F.	No. fish per pound -2,542	2,542-304	304-88.3	88.3-37.8	37.8-19.7	19.7-11.6	11.6-7.35	7.35-4.94	4.94-3.47	3.47-2.53	2.53-
	Approx. size in inches -1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-
36-----	5.3	4.4	3.5	2.6	2.0	1.6	1.3	1.1	1.0	0.9	0.8
37-----	5.5	4.6	3.7	2.8	2.1	1.7	1.4	1.2	1.0	0.9	0.8
38-----	5.8	4.8	3.9	2.9	2.2	1.7	1.4	1.2	1.1	1.0	0.9
39-----	6.0	5.0	4.0	3.0	2.3	1.8	1.5	1.3	1.1	1.0	0.9
40-----	6.3	5.2	4.2	3.1	2.4	1.9	1.6	1.4	1.2	1.0	1.0
41-----	6.6	5.5	4.4	3.3	2.5	2.0	1.7	1.4	1.2	1.1	1.0
42-----	6.9	5.7	4.6	3.5	2.6	2.1	1.7	1.5	1.3	1.1	1.0
43-----	7.2	6.0	4.8	3.6	2.7	2.2	1.8	1.5	1.4	1.2	1.1
44-----	7.5	6.2	5.0	3.8	2.8	2.3	1.9	1.6	1.4	1.3	1.1
45-----	7.9	6.5	5.3	4.0	3.0	2.4	2.0	1.7	1.5	1.3	1.2
46-----	8.2	6.7	5.5	4.1	3.1	2.5	2.1	1.8	1.5	1.4	1.2
47-----	8.6	7.1	5.8	4.3	3.2	2.6	2.2	1.8	1.6	1.4	1.3
48-----	9.0	7.5	6.0	4.5	3.4	2.7	2.3	1.9	1.7	1.5	1.3
49-----	9.4	7.8	6.3	4.7	3.5	2.8	2.4	2.0	1.8	1.5	1.4
50-----	9.9	8.1	6.5	4.9	3.7	2.9	2.5	2.1	1.9	1.6	1.5
51-----	10.3	8.5	6.8	5.1	3.8	3.1	2.6	2.2	1.9	1.7	1.5
52-----	10.7	8.9	7.1	5.3	4.0	3.2	2.7	2.3	2.0	1.8	1.6
53-----	11.2	9.3	7.5	5.6	4.2	3.4	2.8	2.4	2.1	1.9	1.7
54-----	11.6	9.7	7.8	5.8	4.4	3.5	2.9	2.5	2.2	1.9	1.8
55-----	12.2	10.1	8.2	6.1	4.6	3.7	3.0	2.6	2.3	2.0	1.8
56-----	12.7	10.5	8.5	6.4	4.8	3.8	3.2	2.7	2.4	2.1	1.9
57-----	13.4	11.0	8.9	6.7	5.0	4.0	3.3	2.8	2.5	2.2	2.0
58-----	14.0	11.5	9.3	6.9	5.2	4.2	3.5	3.0	2.6	2.3	2.1
59-----	14.5	12.0	9.7	7.2	5.4	4.4	3.6	3.1	2.7	2.4	2.2
60-----	15.1	12.6	10.1	7.6	5.7	4.6	3.8	3.2	2.8	2.5	2.3

* The above recommended amounts are given in pounds per 100 pounds of fish.

fed rainbow trout of different sizes at different water temperatures. Table 13 indicates the amount of dry food to be fed rainbow trout at different water temperatures. These tables have been developed from actual production records. They have not been tested over the complete range of temperatures nor are different food values taken into account. They are the best guides available at this time. They should be followed closely, although minor adjustments may be necessary to meet local conditions.

TABLE 13

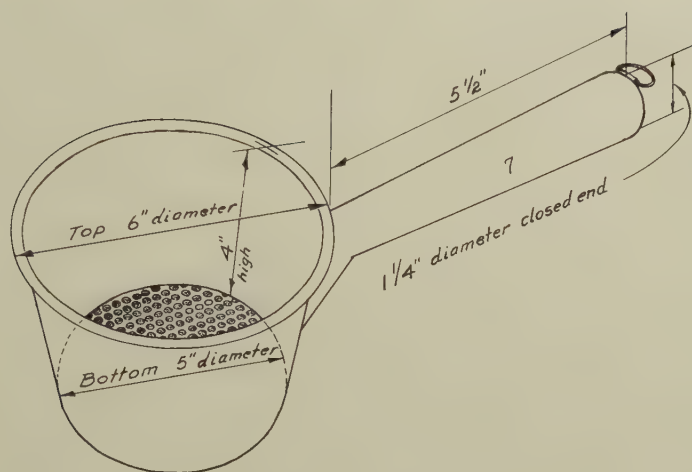
The Recommended Amount of Dry Food to Feed Rainbow Trout Per Day in Percentage of Body Weight, for Different Size Groups Held in Water of Different Temperatures *

Water temperature in degrees F.	No. fish per pound -2,542	2,542-304	304-88.3	88.3-37.8	37.8-19.7	19.7-11.6	11.6-7.35	7.35-4.94	4.94-3.47	3.47-2.53	2.53-
	Approx. size in inches -1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-
36	2.7	2.2	1.7	1.3	1.0	0.8	0.7	0.6	0.5	0.5	0.4
37	2.7	2.3	1.8	1.4	1.1	0.9	0.7	0.6	0.5	0.5	0.4
38	2.9	2.4	2.0	1.5	1.2	0.9	0.8	0.7	0.6	0.5	0.5
39	3.0	2.5	2.2	1.7	1.3	0.9	0.8	0.7	0.6	0.6	0.5
40	3.2	2.6	2.2	1.7	1.3	1.0	0.9	0.8	0.7	0.6	0.5
41	3.3	2.8	2.2	1.8	1.4	1.1	0.9	0.8	0.7	0.6	0.5
42	3.5	2.8	2.4	1.8	1.4	1.2	0.9	0.8	0.7	0.6	0.5
43	3.6	3.0	2.5	1.9	1.4	1.2	1.0	0.9	0.8	0.7	0.6
44	3.8	3.1	2.5	2.0	1.5	1.3	1.0	0.9	0.8	0.8	0.6
45	4.0	3.3	2.7	2.1	1.6	1.3	1.1	1.0	0.9	0.8	0.7
46	4.1	3.4	2.8	2.2	1.7	1.4	1.2	1.0	0.9	0.8	0.7
47	4.3	3.6	3.0	2.3	1.7	1.4	1.2	1.0	0.9	0.8	0.7
48	4.5	3.8	3.0	2.4	1.8	1.5	1.3	1.1	1.0	0.9	0.8
49	4.7	3.9	3.2	2.5	1.9	1.5	1.3	1.1	1.0	0.9	0.8
50	5.2	4.3	3.4	2.7	2.0	1.7	1.4	1.2	1.1	1.0	0.9
51	5.4	4.5	3.5	2.8	2.1	1.7	1.5	1.3	1.1	1.0	0.9
52	5.4	4.5	3.6	2.8	2.1	1.7	1.5	1.3	1.1	1.0	0.9
53	5.6	4.7	3.8	2.9	2.2	1.8	1.5	1.3	1.1	1.1	1.0
54	5.8	4.9	3.9	3.0	2.3	1.9	1.6	1.4	1.3	1.1	1.0
55	6.1	5.1	4.2	3.2	2.4	2.0	1.6	1.4	1.3	1.1	1.0
56	6.3	5.3	4.3	3.3	2.5	2.0	1.7	1.5	1.3	1.2	1.0
57	6.7	5.5	4.5	3.5	2.6	2.1	1.8	1.5	1.4	1.2	1.1
58	7.0	5.8	4.8	3.6	2.7	2.2	1.9	1.6	1.4	1.3	1.2
59	7.3	6.0	5.0	3.7	2.8	2.3	1.9	1.7	1.5	1.3	1.2
60	7.5	6.3	5.1	3.9	3.0	2.4	2.0	1.7	1.5	1.4	1.3
61	7.8	6.5	5.3	4.1	3.1	2.5	2.0	1.8	1.6	1.4	1.3
62	8.1	6.7	5.5	4.3	3.2	2.6	2.1	1.8	1.6	1.5	1.4
63	8.4	7.0	5.7	4.5	3.4	2.7	2.1	1.9	1.7	1.5	1.4
64	8.7	7.2	5.9	4.7	3.5	2.8	2.2	1.9	1.7	1.6	1.5
65	9.0	7.5	6.1	4.9	3.6	2.9	2.2	2.0	1.8	1.6	1.5
66	9.3	7.8	6.3	5.1	3.8	3.0	2.3	2.0	1.8	1.6	1.6
67	9.6	9.1	6.6	5.3	3.9	3.1	2.4	2.1	1.9	1.7	1.6
68	9.9	9.4	6.9	5.5	4.0	3.2	2.5	2.1	2.0	1.8	1.7

* The above recommended amounts are given in pounds per 100 pounds of fish.

Feeding Wet Feeds

Feeding techniques vary with the size of the fish and the type of food being fed. Meat and fish products are fed to fry and fingerlings through a feeding dipper developed for that purpose. The dipper is six inches in diameter at the top. The weight of the food forces it through the perforations in the bottom of the dipper. The food is broken off by agitation of the dipper in the water. Dippers are supplied with holes of



Dipper number	No. of holes per inch	Drill size American wire gauge
2	15	60
3	12	58
4	9	52
5	8	48
6	7	42
7	7	38

FIGURE 34. Feeding dipper.

different sizes for fish varying in size from swim-up fry to five-per-ounce fingerlings (Figure 34). Properly ground meat and fish products are fed rapidly through the dipper.

When starting fish on a meat diet, finely ground beef liver is fed through a No. 2 dipper at the first indication of swimup. It is especially important to start feeding early in cold water, in which the swimup may cover a comparatively long period. Delay in feeding may result in excessive losses over a longer period.

Well-trimmed liver should be ground twice through a $\frac{5}{64}$ -inch plate for fish at 250 per ounce and three times for fish at 400 per ounce. Not over 2 percent of salt should be added as a binder to reduce loss of nutrients through leaching. As the fish grow, the size of the food particles and the perforations in the feeding dipper should be increased.

Fry starting to feed should be fed eight times daily. The daily number of feedings may be reduced to six when the fish reach a size of 80 per ounce. It is not advisable to feed less than four times a day so long as the fish are in troughs or nursery tanks.

Ocean fish added to the diet after the first week of feeding will improve the health and growth of the fish. One-third of the diet should consist of ocean fish when trout and salmon reach a size of 100 per ounce. It should be gradually increased to 50 percent of the diet at 50 per ounce. The ocean fish should be fed on alternate days. There is a danger of thiamin deficiency if mixed with meat, unless fed immediately. In addition, small trout and salmon have a tendency to eat the liver and ignore the fish in a mixed diet.

Once the fingerlings are moved to raceway ponds, they are usually fed by broadcasting the food on the pond with a ladle until they reach a size of about three per ounce (Figure 35). After that they may be fed ocean fish and meat mix by the frozen-block method (Figure 36). Blocks of frozen food are placed in bottomless floating wood frames anchored in the ponds. Two, or preferably three, frames should be evenly spaced in each 100-foot pond. Frames constructed of 1-inch by 6-inch Douglas fir lumber, braced at the corners, are satisfactory. They should be twice as large as a 50-pound package of frozen food to allow the fish free access to the food.



FIGURE 35. Broadcasting wet food to pond fish with a hand ladle.
Photograph by William Schafer, May, 1958.



FIGURE 36. Placing a block of frozen ground food in a floating feeding frame.
Photograph by J. H. Wales, March, 1959.

This method speeds up feeding over the broadcast method and eliminates thawing of the food before feeding. The use of ground beef liver in block feeding has not been successful because of excessive leaching of nutrients and pollution of the water.

Feeding Dry Feeds

Ease and rapidity of feeding, less loss of water-soluble nutrients, and reduction of food preparation time are some of the advantages of starting trout and salmon fry on dry food. However, meticulous care and attention are required. If not fed properly, severe losses will occur.

As in the use of meat products, feeding should be started at the first indication of swimup. The beginning size food, resembling granulated sugar or salt, should be fed at least 10 times daily. In order to be sure that food is available most of the time, the fry should be fed slightly more food than is readily eaten. This should be done only during the early feeding stage.

The food is placed on the surface of the water as carefully as possible by hand or with a modified valve funnel dispenser (Figure 37). Dry food fed in this manner will float for several minutes before breaking the surface tension and slowly sinking to the bottom. With a little practice, the food may be fed as rapidly as a man can walk.

As the fish grow, the size of the food should be increased. Table 14 lists the approximate sizes of food to feed fish of different sizes. The table is conservative and the fish will take larger food at the upper

limits of each size range. Although it is usually better to use food too small rather than too large, delay in increasing the size of the food may lead to gill trouble.



FIGURE 37. Feeding dry feed to hatchery troughs with a modified valve funnel. Food placed on the water surface in this manner will float for a considerable length of time. Photograph by J. H. Wales, May, 1958.

TABLE 14

Size of Dry Food Recommended for Feeding Trout of Various Sizes

Size of food	Size of fish
No. 1.....	120-80 per ounce
Nos. 1 and 2 mixed.....	85-70 per ounce
No. 2.....	75-50 per ounce
Nos. 2 and 3 mixed.....	55-30 per ounce
No. 3.....	35-20 per ounce
Nos. 3 and 4 mixed.....	25-10 per ounce
No. 4.....	15-10 per ounce
No. 4 and crumbles.....	15- 5 per ounce
Crumbles.....	10- 3 per ounce
Crumbles and 3/32-inch pellets.....	5- 2 per ounce
3/32-inch pellets.....	2 per ounce to 9 per pound
5/32-inch pellets.....	9 per pound and larger

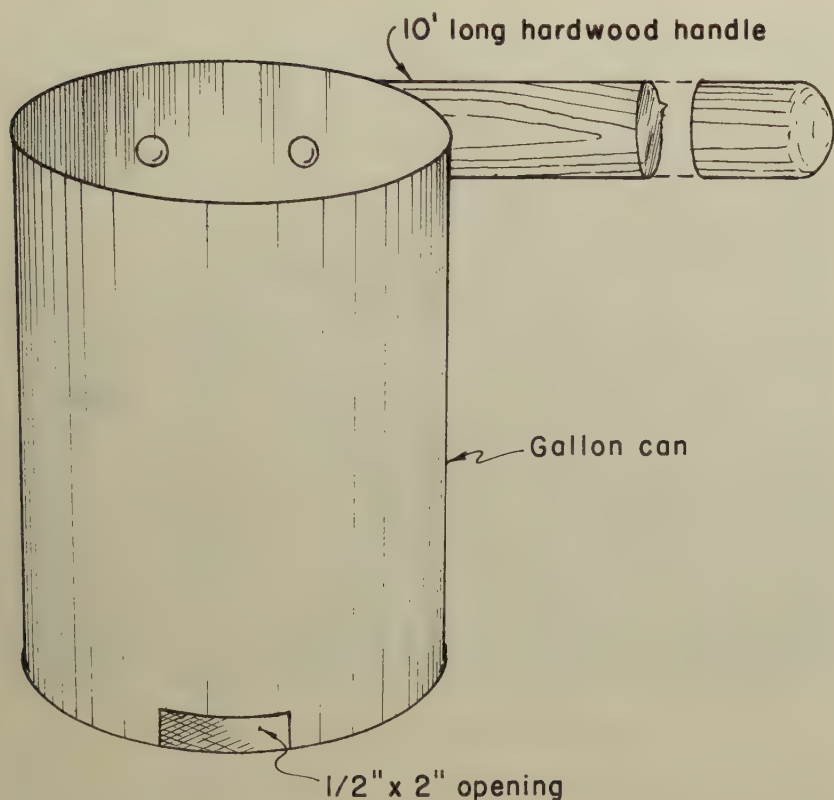


FIGURE 38. Dry food dispenser.

The number of feedings per day may be reduced as the fish grow. Six times daily at 50 per ounce, 4 times at 25 per ounce, and 3 times at 3 per ounce and larger is usually satisfactory.

Trout and salmon started on beef liver may be changed to a dry food diet at any time, although in cold water it may be desirable to wait until they reach a size of 50 per ounce. The change should be made gradually over a period of several days. An abrupt change may cause a severe check in growth and increased mortality.

Figure 38 shows a simple dry food dispenser for feeding fine starter food to small fish in raceway ponds. The device consists of a one-gallon metal can bolted to a 10-foot smooth, wooden handle. A slot about $\frac{1}{2}$ inch by 2 inches is cut in one side of the can directly opposite the side to which the handle is attached. The can is filled about half full with feed and then tipped with the slotted side up to prevent spillage while maneuvering the can over the pond. When the can is tipped in the opposite direction, the food flows out the slot and is slowly spread on the water surface, where it will float for some time.



FIGURE 39. Feeding fish in a series of raceways ponds with a pellet blower.
Photograph by Harold Wolf, July, 1958.

Fish in raceway ponds may be fed pelleted food by broadcasting the food by hand or with a sugar scoop. Wherever pond design permits, the food should be fed with a mechanical pellet blower (Figure 39). This method does a better job of feeding with considerably less labor.

To prevent waste and obtain maximum growth, regardless of what type food is used, it is necessary to feed trout according to body weight and water temperature. This is especially important when feeding dry food. It is necessary to know the number and total weight of the fish in any trough or pond. A weekly feeding schedule should be followed for each body of water. A sample copy of a weekly feeding schedule is shown in Figure 40. *Remember that overfeeding will not materially increase growth.* It will increase the conversion rate and food cost and may lead to serious losses.

Improper feeding technique can lead to serious trouble. One of the most common feeding faults is the tendency to feed the ponds rather than the fish. It is no harder to feed the fish. Care in feeding is always well rewarded.

Table 15 indicates the total amount of dry food of various sizes required to raise 25,000 rainbow trout from swimup to six fish per pound at water temperatures of 46, 51, and 56 degrees F. This table may be slightly altered to meet local conditions. It should be helpful in estimating dry food requirements.

Hatchery _____
 Week of _____ 19____ through _____ 19____. Water temperature _____

[illegible]

FIGURE 40. Hatchery feeding schedule.

TABLE 15
Amount and Types of Dry Food Needed to Raise 25,000 Rainbow Trout From Swimp to Six Per Pound

Size of fish	Length	Total weight in pounds at start of period	Total weight in pounds at end of period	Pounds gained	Percentage of body weight to be fed	Pounds of food to be fed per day	Pounds of food needed	Type of food to be used*	To reach size	Days
<i>Water Temperature 56 Degrees F.</i>										
200/oz.	0.80	7.8	19.5	11.7	7.0	1.4	21.0	No. 1 fry food	80/oz.	15
80	1.25	19.5	52.1	32.6	6.0	3.1	46.5	No. 2 fry food	30	"
30	1.75	52.1	111.6	59.5	5.3	5.8	87.0	No. 3 fry food	14	"
14	2.25	111.6	195.3	83.7	4.6	9.0	135.0	No. 4 fry food	8	"
8	2.75	195.3	347.2	151.9	4.3	14.9	223.5	Crumbles	4.5	"
4.5	3.25	347.2	520.8	173.6	4.0	27.1	406.5	Crumbles	3.0	"
3.0	3.75	520.8	781.2	260.4	3.6	28.1	421.5	Crumbles	2.0	"
2.0	4.25	781.2	1,116.1	334.9	3.3	36.8	552.0	Crumbles	1.4	"
1.4	4.75	1,116.1	1,506.0	389.9	2.7	40.7	610.5	3/32 in. pellets	16.6/lb.	"
5.25	5.25	1,506.0	1,923.0	417.0	2.4	46.2	693.0	3/32 in. pellets	13	"
13	5.75	1,923.0	2,500.0	577.0	2.3	57.5	862.5	3/32 in. pellets	10	"
10	6.25	2,500.0	3,125.0	625.0	2.2	68.8	1,032.0	3/32 in. pellets	8	"
6.75	6.75	3,125.0	3,846.2	721.2	2.1	80.8	1,212.0	3/32 in. pellets	6.5	"
6.5	7.25	3,846.2	4,545.4	699.2	2.0	90.1	1,351.5	3/32 in. pellets	5.5	"
Total				4,537.6			7,654.55			

Requirements

No. 1 fry food	21.0 lbs.
No. 2 fry food	46.5 lbs.
No. 3 fry food	87.0 lbs.
No. 4 fry food	135.0 lbs.
Crumbles	1,116.75 lbs.
3/32 in. pellets	6,248.25 lbs.
Total	7,654.55 lbs.

Conversion = 1.68

Does not provide for losses during period.

TABLE 15—Continued

Amount and Types of Dry Food Needed to Raise 25,000 Rainbow Trout From Swimup to Six Per Pound

Size of fish	Length	Total weight in pounds at start of period	Total weight in pounds at end of period	Pounds gained	Percentage of body weight to be fed	Pounds of food to be fed per day	Pounds of food needed	Type of food to be used*	To reach size	Days
<i>Water Temperature 51 Degrees F.</i>										
200/oz.	0.80	7.8	19.5	11.7	6.0	1.2	24.0	No. 1 fry food	80/oz.	20
80	1.25	19.5	52.1	32.6	5.0	2.6	52.0	No. 2 fry food	30	"
30	1.75	52.1	111.6	59.5	4.3	4.8	96.0	No. 3 fry food	14	"
14	2.25	111.6	195.3	83.7	3.7	7.2	144.0	No. 4 fry food	8	"
8	2.75	195.3	347.2	151.9	3.3	11.5	230.0	Crumbles	4.5	"
4.5	3.25	347.2	520.8	173.6	3.0	15.6	312.0	Crumbles	3.0	"
3.0	3.75	520.8	781.2	260.4	2.8	21.9	438.0	Crumbles	2.0	"
2.0	4.25	781.2	1,116.1	334.9	2.6	29.0	580.0	Crumbles	1.4	"
1.4	4.75	1,116.1	1,506.0	389.9	2.4	36.1	722.0	3/32 in. pellets	16.6/lb.	"
16.6/lb.	5.25	1,506.0	1,923.0	417.0	2.2	42.3	846.0	3/32 in. pellets	13	"
13	5.75	1,923.0	2,500.0	577.0	2.0	50.0	1,000.0	3/32 in. pellets	10	"
10	6.25	2,500.0	3,125.0	625.0	1.9	59.4	1,188.0	3/32 in. pellets	8	"
8	6.75	3,125.0	3,846.2	721.2	1.8	69.2	1,384.0	3/32 in. pellets	6.5	"
6.5	7.25	3,846.2	4,545.4	699.2	1.7	77.3	1,546.0	3/32 in. pellets	5.5	"
Total				4,537.6			8,562.0			

Conversion = 1.88

Does not provide for losses
during period.*Requirements*

No. 1 fry food	24.0 lbs.
No. 2 fry food	52.0 lbs.
No. 3 fry food	96.0 lbs.
No. 4 fry food	144.0 lbs.
Crumbles	1,051.0 lbs.
3/32 in. pellets	7,195.0 lbs.
Total	8,562.0 lbs.

TABLE 15—Continued
Amount and Types of Dry Food Needed to Raise 25,000 Rainbow Trout From Swimup to Six Per Pound

Size of fish	Length	Total weight in pounds at start of period	Total weight in pounds at end of period	Pounds gained	Percentage of body weight to be fed	Pounds of food to be fed per day	Pounds of food needed	Type of food to be used*	To reach size	Days
<i>Water Temperature 46 Degrees F.</i>										
200/oz.-----	0.80	7.8	19.5	11.7	5.0	1.0	30.0	No. 1 fry food	80/oz.	30
80-----	1.25	19.5	52.1	32.6	4.5	2.3	69.0	No. 2 fry food	30	"
30-----	1.75	52.1	111.6	59.5	4.1	4.6	138.0	No. 3 fry food	14	"
14-----	2.25	111.6	195.3	83.7	3.7	7.2	216.0	No. 4 fry food	8	"
8-----	2.75	195.3	347.2	151.9	3.3	11.5	345.0	Crumbles	4.5	"
4.5-----	3.25	347.2	520.8	173.6	2.9	15.1	453.0	Crumbles	3.0	"
3.0-----	3.75	520.8	781.2	260.4	2.5	19.5	585.0	Crumbles	2.0	"
2.0-----	4.25	781.2	1,116.1	334.9	2.2	24.5	735.0	3/32 in. pellets	1.4	"
1.4-----	4.75	1,116.1	1,506.0	389.9	2.0	30.1	903.0	3/32 in. pellets	16.6/lb.	"
16.6/lb.-----	5.25	1,506.0	1,923.0	417.0	1.8	34.6	1,038.0	3/32 in. pellets	13	"
13-----	5.75	1,923.0	2,500.0	577.0	1.6	40.0	1,200.0	3/32 in. pellets	10	"
10-----	6.25	2,500.0	3,125.0	625.0	1.5	46.9	1,407.0	3/32 in. pellets	8	"
8-----	6.75	3,125.0	3,846.1	721.1	1.4	53.8	1,614.0	3/32 in. pellets	6.5	"
6.5-----	7.25	3,846.1	4,545.4	699.3	1.3	59.1	1,773.0	3/32 in. pellets	5.5	"
Total-----				4,537.6			10,506.0			

Conversion = 2.3

Does not provide for losses during period.

Requirements

No. 1 fry food-----	30.0 lbs.
No. 2 fry food-----	69.0 lbs.
No. 3 fry food-----	138.0 lbs.
No. 4 fry food-----	216.0 lbs.
Crumbles-----	1,458.0 lbs.
3/32 in. pellets-----	8,595.0 lbs.
Total-----	10,506.0 lbs.

* Size based on type of food presently produced by reliable fish feed companies.

GRADING FISH

It has been said that a hungry trout three inches long will devour a trout one and one-half inches long, providing he can catch it, and that a six-inch trout will eat a three-inch trout, and so on up the line, until the word cannibalism becomes frightening. There just isn't any question that large trout will eat small trout. Both trout and salmon are handled in comparatively large numbers when reared in troughs or ponds. Therefore, any lot of fish of fair numbers must consist of the offspring of several females. This, plus the fact that all of the eggs from a single female are not always of the same size, and the fact that the larger fish in any group are better able to compete for food than the smaller fish, explains some of the reasons why trout and salmon grow irregularly in size.

Grading of fish is necessary to get good growth, reduce cannibalism, prevent competition between fish of smaller size with their larger kin, and obtain fish of the correct size to meet management requirements. Furthermore, the total weight of fish in any one group can be more accurately determined for computing the amount of food to feed in percentage of body weight, if the fish are of a nearly even size. Grading equipment has been designed which will grade fish to a number of sizes in one operation. Grading in more sizes than is necessary, however, is time consuming and normally grading one group of fish into three sizes—small, medium, and large—is sufficient.

Many types of fish-grading devices are currently in use for segregating the various sizes of fish from the time they hatch until they are ready for release in the stream. Each of these devices has been developed to operate under a certain set of conditions to accomplish a desired objective. All of them are efficient to some degree and can be adapted to almost all situations, with varying degrees of efficiency.

Fish graders most commonly used in California are the Murray-Hume Automatic Grader, or a modification, and the Morton Adjustable Grader.

Murray-Hume Automatic Grader

The Murray-Hume bar grader (Figure 41) was developed to grade fish in a standard raceway type pond without having to lift the fish from the water.

The grader consists of a number of $\frac{1}{2}$ -inch diameter aluminum tubes placed vertically and equal distance apart in a 2-inch by 2-inch angle aluminum frame.

Each grader frame will accommodate two space settings; one has a $\frac{5}{8}$ -inch opening for grading out fish weighing 6 per pound, the other an opening of $\frac{35}{64}$ -inch to grade out fish weighing 8 per pound. The grader used with the standard California type raceway is 5 feet $2\frac{1}{4}$ inches wide by 2 feet 4 inches high and is constructed to fit the keyway in the standard pond trunk.

The grader is placed in the upstream end of the pond trunk (Figure 42). The fish are pulled into the trunk behind the grader with a seine and then crowded against the grader with a push rack. Fish small enough to pass through the grader swim into the pond above. Those unable to pass through remain in the pond trunk behind the grader, where they can be temporarily held for planting or other purposes.

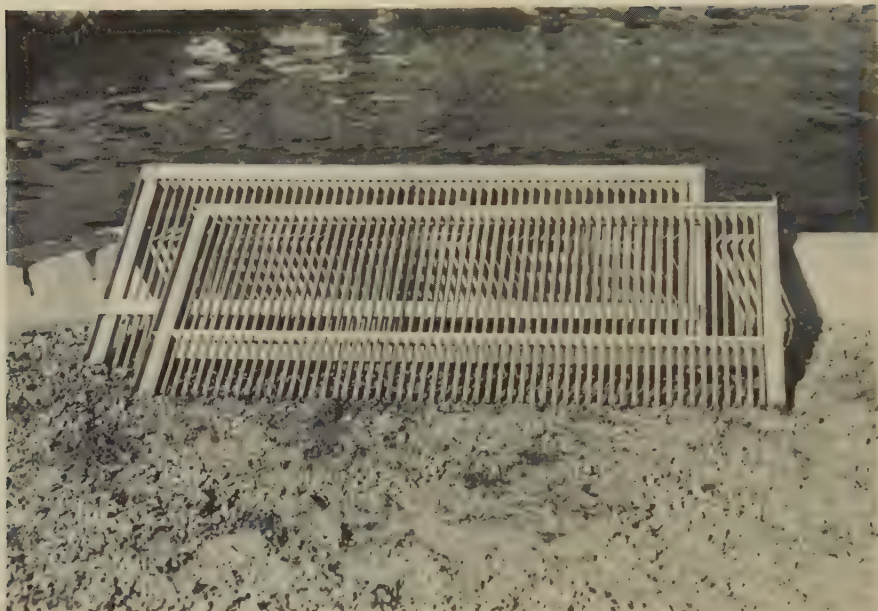


FIGURE 41. A set of Murray-Hume parallel bar grading racks. Each rack has space settings for grading two sizes of fish. Photograph by J. H. Wales, October, 1958.

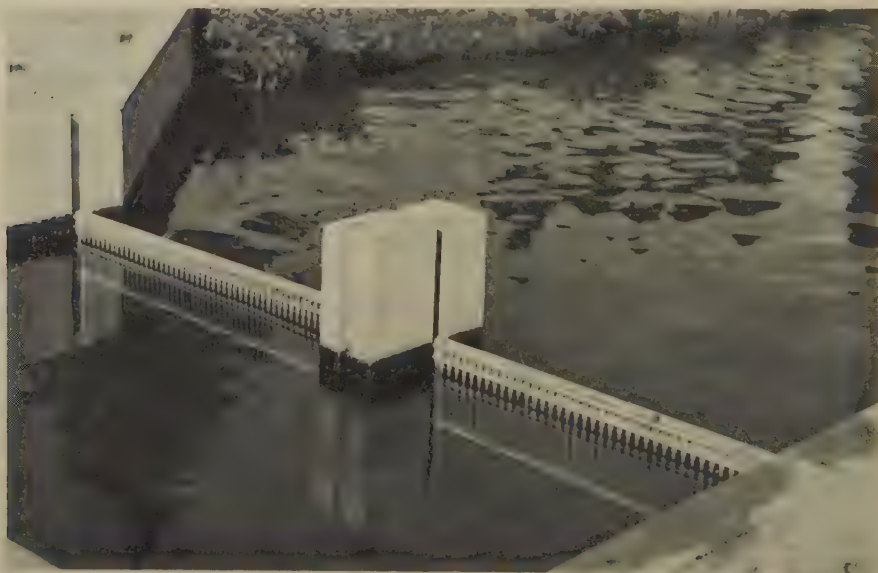


FIGURE 42. Murray-Hume fish grading racks set in pond trunk for automatic grading. Photograph by J. H. Wales, October, 1958.

The flow and water depth of the pond should be held at normal operating levels during the grading operation. The time required to grade a pond of fish varies from only a few minutes to two hours, depending somewhat on local conditions. Several graders can be operated at one time in the same pond series, should the need arise.

The advantage of the Murray-Hume grader over most other graders is that it is almost automatic. The only operation required is that of selecting the size of spacing desired, setting the grader in place, and seining in the fish behind it. From there on the attendant can continue with other duties, and within a short time the fish have graded themselves with a minimum of handling.

The following materials are necessary to construct a Murray-Hume grader to fit the standard California raceway pond.

- 2 pieces—2 in. x 2 in. x $\frac{1}{4}$ in. Tee (Duval No. 6061-T-6), 2 ft. 4 in. long
- 2 pieces—2 in. x 2 in. x $\frac{1}{8}$ in. Tee (Duval No. 61-S-T-6), 5 ft. 2 $\frac{1}{4}$ in. long
- 56 pieces— $\frac{1}{2}$ in. O.D. tube, aluminum, 16 gauge, 3 S $\frac{1}{2}$ hard, 2 ft. 3 in. long
- 1 piece— $\frac{1}{8}$ in. aluminum welding rod
- 1 piece— $\frac{1}{2}$ in. O.D. tube, aluminum, 16 gauge, 3 S $\frac{1}{2}$ hard, 5 ft. 2 $\frac{1}{4}$ in. long
- 57 only— $\frac{1}{4}$ in. x 1 in. aluminum hex head screw

Spacing of holes on 1 $\frac{1}{8}$ -inch centers will give a $\frac{5}{8}$ -inch clear opening, and will grade out fish weighing 6 per pound.

Using a 1-3/64-inch center to center setting for a 35/64-inch opening will grade fish averaging 8 per pound.

Morton Adjustable Grader

The Morton Adjustable Grader permits grading of fish into as many as five sizes in one operation and it may be adjusted to grade a wide range of sizes.

Briefly, the Morton grader consists of a number of round metal tubes placed in a double rack one above the other and set on an incline, with the spacing smaller at the upper end than at the lower. Water is sprayed over the grading racks to keep the fish moist and to assist their passing over the racks. The grader is supported on four legs about waist-high (Figure 43), and can be moved from one location to another as required. Fish are dipped up and poured onto the upper end of the grader and the various sizes are graded into separate compartments.

The most important step in adjusting the Morton grader is to obtain a grader setting which will permit the best segregation of the fish. This can be done by using a pair of outside and inside diameter calipers. A small fish, representing the group of small fish in the lot to be graded, is taken and the outside calipers snugly adjusted to the thickest part of its body. This caliper reading is then transferred to the inside caliper, which is used in setting the spacing at the upper end of the grader.

The next step is to select a fish representative of the largest group in the lot, with the same procedure followed as for the smallest fish. When the spacing at the lower end of the grader has been set for the largest fish, the grader is ready to grade that particular lot of fish. The smallest spacing obtainable on the Morton grader is one-fourth inch, which is sufficient for grading fish running 60 per pound and smaller. To illustrate the variation in size in a particular group of fish, 174,634



FIGURE 43. Morton adjustable fish grader. Photograph by Sartorius Company, Inc., San Francisco, California.

rainbow averaging 63.1 per pound gave the following results when graded with a Morton grader.

<i>Pounds</i>	<i>Fish per pound</i>	<i>Number of fish</i>	<i>Percentage of total</i>
474 -----	38.0	18,012	10.31
496 -----	49.0	24,304	13.91
777 -----	63.0	48,951	28.03
575 -----	80.0	46,000	26.34
331 -----	113.0	37,403	21.42

WEIGHING AND ENUMERATING FISH

A fish hatchery, like any other business, must account to its stockholders in terms of number, size, and weight of fish produced, as well as maintain a running inventory of fish on hand for proper feeding and management. Any system of accounting is time consuming and costly and, in the case of hatcheries, the difficulties are increased by the fact that the system must be based on the determination of size of

millions of small fish that are delicate, very active, and must be handled with care. Three sizes of fish are produced and distributed by California hatcheries: fingerlings, subcatchables, and catchables. The number of fish per ounce or pound, regardless of size, is determined with a suspended spring balance scale (Figure 44). The number of fingerlings in a shipment is determined with the same scale. Subcatchables



FIGURE 44. Spring balance scale suspended over hatchery trough for weighing fingerlings. Photograph by J. H. Wales, January, 1959.

and catchables may be weighed by the scale method or the displacement method, employing a fish loader (Figure 45) and a tank truck with sight gauge (Figure 46). Instructions for weighing and recording fish for transfer or shipment follow.



FIGURE 45. Fish loader for loading catchable-size fish into planting trucks. Displacement method of weighing fish is used. Sight gauge on back of truck is calibrated in increments of 50 pounds for accurate reading. Photograph by William M. Carah, May, 1956.

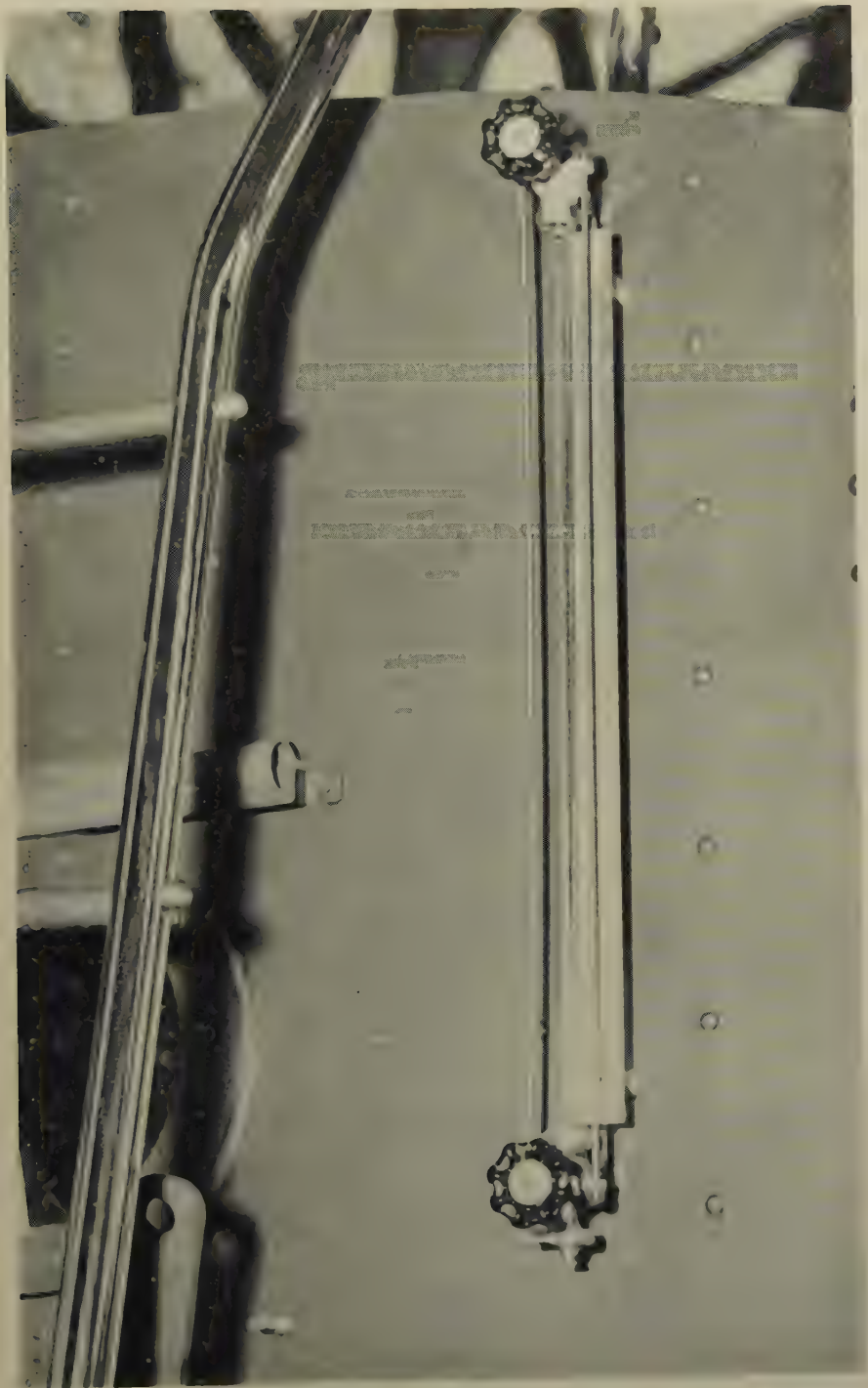


FIGURE 46. Glass sight gauge with calibrated metal marker strip on fish planting tank for weighing fish by displacement method. Photograph by William M. Carah, 1956.

Fingerlings—Scale Method

When fish average one or more to the ounce, they are classed as fingerlings and the weight is recorded in ounces.

A suspended type of spring balance scale is used in weighing all fingerlings.

The dial of the scale is divided into 80 ounces and records 15 pounds in three revolutions of the pointer. Any support used for suspending the scale over the trough or pond should be readily portable and of a type that leaves the working area entirely clear, with no overhanging projections.

A three-gallon lightweight bucket should be used. After the support and scales are set up, the bucket is hung on the scales and filled with water until the pointer comes to about 70 on the first revolution. Enough water is added with a dipper to bring the pointer to zero. This leaves a capacity of 160 ounces for weighing fish.

Before starting the count it is necessary to determine by actual hand count the number of fish per ounce. This is the sample upon which calculations of the number of fish are based. The sample count should be very accurate. In order to get a random sample the fish should be concentrated, which makes the fish easier to catch and provides a more accurate sample.

To make the sample count, fish are poured from the dip net into the bucket until a predetermined number of ounces is reached.

To determine the number of fish per ounce, the fish are counted from the bucket and the number of fish counted is divided by their weight in ounces.

Example: Ten ounces of fish are counted and found to number 160. Number of fish (160) divided by the number of ounces (10) equals number of fish per ounce (16), or:

$$10 \overline{) 160} \begin{array}{l} 16 \text{ fish per ounce} \\ 160 \end{array}$$

In counting into cans, the number of ounces weighed into each can is multiplied by the number of fish per ounce. This number multiplied by the number of cans equals the total number of fish.

Subcatchables and Catchables—Scale Method

When fish average less than one per ounce and more than six per pound, they are classed as subcatchables. Fish weighing six per pound and larger fish are classed as catchables. The weight of both classes is recorded in pounds.

A suspended type of spring balance scale of 60-pound capacity is used in determining the number of fish per pound.

The dial of the scale is divided into ounces and pounds and records 60 pounds in three revolutions of the pointer.

A six-gallon bucket should be used. Water is added until the pointer makes one revolution to zero. This leaves a capacity of 40 pounds for weighing fish. Ordinarily, the fish should be weighed in increments of 10 or 20 pounds to facilitate calculation.

The procedure is the same as the one used in enumerating fingerlings, except that pounds are used instead of ounces.

When weighing fish, it is necessary that an accurate count be kept of the number of buckets weighed and placed in cans. To keep count of the number of buckets weighed without the use of some mechanical aid is not practical. One of the most satisfactory procedures is to use a hand tally register (see specifications). The hand tally register can, in most instances, be fastened to the scale support within easy reach of the person doing the weighing. Thus, each bucket of fish weighed can be tallied as it is taken from the scales.

Scale Specifications

Scales, for weighing *fingerlings*: "Chatillion", hanging, graduated in ounces, 80 ounces per revolution, capacity 240 ounces, 8-inch dial.

Scales, for weighing *subcatchables* and *catchables*: "Chatillion", hanging, graduated in ounces, 20 pounds per revolution, 60-pound capacity, 7-inch dial.

Bucket, for weighing *subcatchables* and *catchables*: 6-gallon, 24-gauge steel, with bail handle, no lid, straight sides, unpainted or treated, type normally used for paint containers.

Counter hand tally: Braun-Knecht-Heimann Company No. 23661, tallies from 1 to 10,000.

Displacement Method

The displacement method of weighing fish is based on the weight of water displaced by a pound of fish. This method is used when transporting fish larger than 16 per pound in tanks.

Specific gravity tests have shown that in the size range from 1 to 16 per pound an average of 1.018 pounds of trout displace one pound of water. The standard deviation in these tests was 0.0102.

The figure 1.018 was rounded off to 1.02. Therefore, the total pounds of water displaced multiplied by 1.02 equals the pounds of trout loaded.

Example: 1,100 pounds of water $\times 1.02 = 1,122$ pounds of trout.

All that is needed to convert a planting tank to this method is a sight gauge mounted near the top of the tank. This consists of an 18-inch length of $\frac{1}{2}$ -inch glass boiler water gauge mounted vertically on the tank beside a strip of brass channel. It is important that the tube and the brass channel be exactly parallel.

The first step in calibrating the gauge is to fill the tank with water. The water is drawn down to the top of the sight gauge and the level marked on the brass channel with a pencil. A combination square placed across the channel with the blade extended to the glass tube helps make the mark accurate.

The water is drawn off into a tub, set on a platform scale, in specified increments: 100, 50, and 25 pounds. The channel is marked at the level of each increment.

Care must be taken to guard against splashing. Any water accidentally drawn off in excess of the increment should be returned to the tank before marking the channel.

The importance of extreme accuracy in this operation cannot be overemphasized. All the fish loaded into the tank will be measured by the gauge.

When the desired number of marks has been made on the brass channel, it is removed and placed in a vice and the pencil marks are scribed into it.

Before loading the fish, the truck is filled with water well above the mark indicating the size of the load desired and driven to the loading location.

Surplus water is drawn off until the water is exactly even with the starting mark. It is not necessary that the tank be level. However, if the truck is moved during loading, the amount of fish loaded should be noted and a new starting point selected for the remainder of the load.

Weight samples are taken in the usual manner to determine the size of the fish being loaded, the number of fish per load being determined by multiplying the number of fish per pound by the number of pounds of fish loaded.

When loading with a fish loader, the truck is positioned, the water is drawn off to the selected point, and loading is begun. At hatcheries not equipped with a fish loader, the fish are dipped directly into the tank.

LENGTH-WEIGHT RELATIONSHIP IN RAINBOW TROUT

Condition Factor

The ratio of length to weight in trout is often expressed as the condition factor. It is an index to the weight of a fish in relation to its length and is the yardstick often applied when checking growth rate or determining the amount of food to be fed at fish hatcheries.

The factor is obtained from the following equation: $C.F. = \frac{W \times 100,000}{L^3}$, in which C.F. equals the coefficient of condition in the

TABLE 16
Number of Rainbow Trout Per Unit of Weight by Length

Fork length in inches	Number fish per ounce	Number fish per pound	Fork length in inches	Number fish per ounce	Number fish per pound
1.1- 1.3	65-100	---	8.0- 8.2	---	4.39
1.4- 1.6	35-64	---	8.3- 8.5	---	3.38
1.7- 1.9	20-34	---	8.6- 8.8	---	3.35
2.0- 2.2	12-19	---	8.9- 9.1	---	3.25
2.3- 2.5	8.80	---	9.2- 9.4	---	3.15
2.6- 2.8	6.80	---	9.5- 9.7	---	2.80
2.9- 3.1	5.40	---	9.8-10.0	---	2.53
3.2- 3.4	3.96	---	10.1-10.3	---	2.34
3.5- 3.7	3.10	---	10.4-10.6	---	2.18
3.8- 4.0	2.33	---	10.7-10.9	---	2.02
4.1- 4.3	1.86	---	11.0-11.2	---	1.89
4.4- 4.6	1.56	---	11.3-11.5	---	1.75
4.7- 4.9	1.30	---	11.6-11.8	---	1.60
5.0- 5.2	1.10	---	11.9-12.2	---	1.45
5.3- 5.5	---	15.28	13	---	1.13
5.6- 5.8	---	12.74	14	---	0.91
5.9- 6.1	---	10.84	15	---	0.73
6.2- 6.4	---	9.52	16	---	0.61
6.5- 6.7	---	8.25	17	---	0.50
6.8- 7.0	---	7.51	18	---	0.42
7.1- 7.3	---	6.30	19	---	0.36
7.4- 7.6	---	5.35	20	---	0.31
7.7- 7.9	---	4.46			

English system, W is the weight of the fish in pounds, L is the length in inches (usually fork or total length), and 100,000 equals the factor which places the decimal point, usually at the right of two significant figures.

The length-weight relationships of California hatchery rainbow trout are given in Table 16.

TRANSPORTATION OF TROUT AND SALMON

The modern refrigerated fish transport truck (Figure 47) is a highly specialized piece of equipment with numerous pipes, heat exchangers, and pumping equipment. Only clean water should be used. This is necessary to prevent foreign matter from becoming clogged in the circulating system and reducing its efficiency, and to prevent development of a toxic condition. Foul water from a previous load of fish may remain in the pump chambers and other parts of the system in sufficient amounts to affect the following load adversely. For this reason it is absolutely essential always to flush out fish planting tanks and the circulating system before filling with water for the next load.

Effects of Metabolic Waste Products on Fish During Transportation

Not a great deal is known about the effects of waste products of metabolism on trout and salmon in pond management and in fish



FIGURE 47. 1,500-gallon fish transport truck. Electric aeration and refrigeration equipment is driven by generators mounted at top of mechanical compartment.
Photograph by Harold Wolf, July, 1958.

transportation. It is known, however, that ammonia, urea, uric acid, carbon dioxide, and other products of metabolism can create a toxic condition. When the concentration of ammonia and other excretory products increases in the water, trout lose the ability to use oxygen and the blood picture changes drastically. For example, as the ammonia concentration increases to one part per million, the oxygen concentration in the blood decreases to about one-seventh normal, and the carbon dioxide content increases about 15 percent, with resulting suffocation.

Carbon dioxide may be one of the major limiting factors in fish transportation. It has been shown that (a) whenever carbon dioxide is kept below 15 p.p.m. with reasonable values of oxygen and temperature, the fish remain in good condition, and (b) when carbon dioxide reaches about 25 p.p.m., the fish become distressed.

Measures which may reduce the accumulation of metabolic wastes are:

1. *Starvation of fish before shipment.* Fish should not be fed for at least 36 hours before transportation when reared on dry feeds and 48 hours when reared on frozen meat and fish products.

2. *Maintenance of low temperatures.* The most suitable temperature range for transporting fish in tanks is from 47 to 53 degrees F.

3. *Use of hypnotic drugs.*

4. *Removal of metabolic products.* This may be accomplished by aeration or the addition of buffering agents. Lime water has been satisfactorily used as a buffering agent to control carbon dioxide in experimental tests. However, this is not practical under operating conditions. Further experiments along this line are necessary.

Sodium Amytal in Fish Transportation

Sodium amytal, one of the many hypnotic barbiturates available, produces a slow-reacting, long-lasting tranquilizing effect on trout and salmon. Some speculation remains as to why sodium amytal is an aid in fish transportation. Two theories have been advanced along this line; one is that the drug slows down the activity of the fish, thereby reducing its oxygen requirements, and the other is that sodium amytal slows down the entire catabolic process, with a general reduction of metabolic wastes which affect oxygen consumption in fish.

The concentration at which sodium amytal has been used in fish transportation varies considerably. The most satisfactory dosage is generally one-half grain per gallon of water. At this low concentration the carrying capacity of fish transportation trucks can be greatly increased and very often doubled. The effectiveness of the drug is, to some extent, regulated by temperature. It appears to decrease when the temperature rises above 54 degrees F., the most effective range being from 47 to 54 degrees F.

Use of Antifoam Emulsion

The formation of foam and scum, especially when drugs are used in transporting fish, often becomes quite bothersome. This is especially true when long hauls of heavy loads are being made. Foam on the surface of the water makes it difficult to observe the fish being carried. Foam and scum will also dry on the tank surfaces and must be cleaned off. The formation of foam and scum can be prevented by the use of

Dow Corning Antifoam AF Emulsion. The Antifoam AF Emulsion is available as a 30 percent concentration of the Dow Corning Antifoam A, in water and emulsifiers.

Diluting the emulsion to a 10 percent solution in warm water (9 parts water, 1 part emulsion), makes it easy to measure and handle. For dilutions of the AF Emulsion, use any convenient measuring vessel.

Maximum effectiveness of the emulsion can best be realized by adding the Antifoam AF Emulsion before adding either drug or fish. When introduced into the tank the emulsion may impart a slightly turbid or opaque quality to the water. This nontoxic additive has a wide latitude of effectiveness and is very easy to use. Foaming can be controlled by adding Antifoam Emulsion, one ounce or 25 cc. of the 10 percent dilution for every 100 gallons of water.

TROUT AND SALMON DISEASES

This section refers primarily to specific fish diseases which principally concern fish culturists in California. It should be borne in mind that there are others which are extremely important in other states.

Some diseases occur at certain hatcheries at regular intervals. When fish culturists are aware of this, there often is sufficient forewarning to treat the fish before the disease reaches a serious stage.

Symptoms

When organisms become numerous on a fish, they may cause changes in its behavior or produce other obvious symptoms. Unfortunately, each disease or parasite does not always produce a single symptom or syndrome characteristic in itself. Nevertheless, by observing the symptoms one can usually narrow down the cause of the trouble.

Some of the obvious changes in behavior of fish suffering from a disease, parasite, or other physical affliction are: (1) loss of appetite, (2) abnormal distribution in pond, such as riding the surface, gathering at the pond sides or in slack water, and crowding the head or tail screens, (3) flashing, scraping on bottom or projecting objects, darting, whirling, or twisting, and loss of equilibrium, and (4) loss of vitality, weakness, and loss of ability to stand handling during grading, seining, loading, or transportation.

In addition to changes in behavior, disease may produce physical symptoms, or the parasite may be seen by the unaided eye. For microscopic examination, it is necessary to call in a fish disease expert. Symptoms observed may be external or internal, or a combination of both.

Gross external symptoms are: (1) discolored areas on the body, (2) eroded areas or sores on the surface of the body, head, and fins, (3) swelling on the body or gills, (4) popeye, (5) hemorrhages, and (6) cysts containing parasites.

Gross internal symptoms are: (1) color changes of organs or tissue (pale liver or kidney or congested organs), (2) hemorrhages in organs or other tissues, (3) swollen or boil-like lesions, (4) change in texture of organs or tissues, (5) accumulated fluid in body cavities, and (6) cysts containing parasites.

Diseases and Parasites

Before taking up specific diseases, it will be best to describe briefly a general classification of disease-causing organisms among fish. The majority of such organisms may be placed in two groups. One is the plant kingdom. Bacteria and fungi belong to this group. The other is the animal kingdom. Forms belonging to this group vary from the relatively simple, single-celled animals (Protozoa) to the complex, multicelled organisms (Metazoa) such as worms, copepods, and mussels.

In addition, there are two other classes of diseases important to fish culturists. One is nutritional in nature, the other is caused by virus. As previously mentioned, diseases or parasites may be found externally or internally, or both in some cases.

External Bacterial Diseases

Columnaris

Columnaris disease is caused by *Chondrococcus columnaris* and is known to many fish culturists. It is not restricted to salmonids, but is also found on many warmwater fishes. This organism, although studied by a number of investigators, remains confusing to specialists. Because of details in its life history, some workers refer to the organism as *Cytophaga columnaris*. This disease is most prevalent in California when water temperatures rise above 56 degrees F. It affects fish ranging in size from small fingerlings to large catchables. The early symptoms are grayish-white areas on the body, head, fins, or gills. On careful observation, the edges of these lesions may appear reddened and hemorrhaged. The early lesions may start at a weakened or injured area and spread. In some advanced cases the fish may be almost entirely covered by the lesions. The lesions are often invaded secondarily by fungus. At this stage, these areas appear fuzzy or furry.

Although some workers consider this disease to be external in nature, others have shown it to be also internal even if the lesions are not as obvious or may be lacking. The best success in treating columnaris in California has been obtained by either dipping or flushing with copper sulfate and feeding sulfamerazine or sulfamethazine at 10 grams of drug per 100 pounds of fish daily for a 5- to 10-day period. It may be necessary to give more than one copper sulfate treatment to control the surface bacteria. When treating salmon, PMA (pyridylmercuric acetate) instead of copper sulfate may be used as a prolonged bath at a concentration of 1:500,000 to 1:1,000,000. However, it should be borne in mind that PMA has yielded variable results with rainbow trout and steelhead.

When water temperatures are high and fish are crowded, the disease will recur; under such conditions the treatment only controls the disease and does not eliminate it. In order to keep columnaris in check, it is necessary to give repeated treatments.

Bacterial Gill Disease

This disease is one of the most common in California, and year in and year out probably causes more losses than any other. Rainbow trout, as well as salmon, may be infected. The bacterium responsible for most cases of bacterial gill disease is probably an unidentified species

related to *Chondrococcus columnaris*. The conditions under which this organism flourishes are water temperatures above 56 degrees F. and crowding of the fish.

In early stages the gills may be swollen and clubbed, with large amounts of mucus present. The fish may be weak, crowd the pond tail screens, ride high in the water, and "go off feed". In some cases there is much destruction of the gill tissue. The necrotic tissue in these cases is grayish-white and many of the gill filaments may be completely eroded. Quite often the gills on one side only are affected.

Generally in California, dipping or flushing with copper sulfate affords control. This probably is due to the fact that the organism is restricted to the gills. On occasions, when external treatments do not provide adequate control, it is necessary to feed sulfa drugs in the manner described for columnaris. This is probably necessary because the organism has invaded the internal tissues. Fungus may be found as a secondary invader on the gills of infected fish. Bacterial gill disease may be found in salmonids ranging in size from fingerlings to catchables.

Peduncle Disease

In California this disease, while not common, can cause serious mortalities when it occurs. It is seen most often in fingerling rainbow trout but also infects catchables and other species of salmonids. Unlike columnaris, it occurs at temperatures below 56 degrees F. as well as at higher temperatures and fish need not be crowded for it to appear. The organism believed responsible for this disease is an unidentified bacterium. The tissue of the caudal fin and peduncle is affected. In early stages it may involve only the tail; later it involves the peduncle, causing much tissue destruction. Advanced stages result in complete loss of the caudal fin and the posterior end of the peduncle, leaving exposed muscle and bone of the vertebral column. Sometimes the peduncle is involved before the caudal fin.

No treatment to date has been very effective. Copper sulfate dips (1:2,000) and sulfa therapy have yielded the best, but admittedly not spectacular results. PMA so far has been ineffective.

Fin Rot

Bacterial fin rot is not common in California. It is caused by an unidentified bacterium. In the early stages a white discoloration is present along the outer edge of the fins; as the disease advances, this moves toward the base of the fins. The tissues, including fin rays, are destroyed, although the rays are lost more slowly and usually appear as ragged remnants.

Quite often when crowded, rainbow trout will develop a dorsal fin rot which superficially resembles bacterial fin rot. It shows a smooth white-thickened fin margin and lacks the ragged appearance and eroded fin rays of the bacterial fin rot.

Dipping of infected fish in a 1:2,000 solution of copper sulfate usually is effective in controlling bacterial fin rot.

Internal Bacterial Diseases

Furunculosis

This bacterial disease, caused by *Aeromonas salmonicida*, has appeared in records of fish disease since 1894 and is believed to be limited to freshwater and anadromous fishes.

This disease has caused severe mortalities in hatchery and wild trout. Rainbow trout are generally considered to be among the more resistant to furunculosis, but they do get the disease and can provide a source of infection for other fish. In the past, this disease was one of the most feared because no adequate treatments were known. With the advent of the sulfa drugs, however, a major step forward was taken, and at the present time there is little excuse for encountering the hatchery losses which once resulted from furunculosis.

In yearling and older fish, the disease is usually marked by a series of open sores on the body. Usually one can find a combination of open sores and raised boil-like lesions. The disease is essentially a "blood poisoning". The bacteria are carried about in the blood. They may collect in clumps in the smaller blood vessels, then rupture the blood vessels and invade the surrounding tissues.

The lesions and sores produced may appear to the unaided eye as swollen red spots beneath the skin. As the disease progresses these spots may fuse, destroying the tissue and enlarging into a definite swollen area. These areas may break open on the outside of the fish, forming good-sized ulcers. Sometimes the bacteria cause soft and blister-like lesions filled with blood. The gills may also show hemorrhaged areas.

There may be a marked congestion of blood vessels in the body cavity. The lining of the intestine may be inflamed and there may be a discharge of blood and mucus from the vent, especially after death. The spleen may be enlarged and be a bright cherry red; this is particularly true in fingerling trout. The kidney is usually badly diseased and may be converted to a semi-liquid mass. Trout may die before advanced sores and boils form. In fingerlings, frequently, the only evident symptoms are dark irregular areas on the sides between the dorsal and pectoral fins, which may also become affected and be reduced to nothing more than the rays.

There are a number of sulfa drugs which have been recommended for treating furunculosis. Two dosages reportedly satisfactory are:

1. Twelve grams of sulfamerazine, plus 6 grams of sulfaguanidine, mixed into the feed for each 100 pounds of trout. This should be fed for three days. Then the mixture should be changed to 6 grams of sulfamerazine, plus 4 grams of sulfaguanidine for 7 days. The originator of this method suggests that it not only controls furunculosis but eliminates the disease.

2. Sulfamerazine fed at the rate of 8 grams per 100 pounds of trout until the loss drops to normal, and then continued for the number of days it takes to reach normal loss.

Ulcer Disease

As the name implies, this disease, caused by *Hemophilus piscium*, is characterized by ulcers or sores on the surface of the fish. These resemble furunculosis but are essentially different in that the "sores" begin on the outside and work through the skin, whereas in furunculosis

they develop beneath the skin as blood-filled boils and may eventually break open on the outside if the fish lives long enough. Ulcer disease "sores" are often circular in outline, though they may be irregular. Another important characteristic of the disease is the frequent infection of the jaws and roof of the mouth.

Recommended treatments are the use of chloramphenicol or terramycin in the food at the rate of $2\frac{1}{2}$ to $3\frac{1}{2}$ grams of pure antibiotic activity per 100 pounds of fish per day until losses have dropped to "normal".

Red-mouth Disease

Various bacteria, such as *Pseudomonas hydrophila* and an unidentified paracolon, have been isolated from fish with this disease. The bacteria which cause this disease are carried to all parts of the body by the blood. The usual symptoms used to distinguish this disease from other similar bacterial diseases of trout are inflammation of the skin lining the mouth, presence of small red spots or hemorrhages on the gill membranes or throat and in the gills themselves, and occasionally inflammation and ulceration of the bases of the fins. When the fish is cut open, the inflammation and hemorrhages can often be seen in the posterior part of the intestine, in the fat which is attached to the viscera, on the inner wall of the body cavity, and in the liver. Unfortunately, these symptoms are not always present, and in some cases it is necessary to examine the blood with a microscope. The same or a similar bacterium has been found in other species of fishes, and it is not impossible that the disease can be spread by feeding infected "rough" or "scrap" fish.

Trout with red-mouth disease may be treated with sulfa drugs. The common method is to feed Sulmet at the rate of 8 grams per 100 pounds of trout. This treatment may be followed until the loss of fish has dropped to approximately "normal", then continued for the same number of days. However, this concentration and length of treatment have not been thoroughly worked out. Another variation of the sulfa treatment combines sulfamerazine and sulfaguanidine: 12 grams of sulfamerazine and 6 grams of sulfaguanidine per 100 pounds of trout for 3 days, then a reduced dosage of 6 grams of sulfamerazine and 4 grams of sulfaguanidine for 7 days.

Fish Tuberculosis

For many years organisms related to the human tuberculosis bacterium have been reported from fish. Extensive work is being done in the Pacific Northwest on this problem, as related to salmonids. In California, fish tuberculosis has been found recently in adult king salmon, steelhead, and silver salmon.

In these fishes, the disease appears similar to miliary tuberculosis in human beings. The lesions are caseous or purulent tubercles scattered in the kidney, liver, spleen, and digestive tract. Its full significance to anadromous fishes is not well understood, but could play an important role in the well-being of a fishery. At present there are no drugs which control the disease in fish. Elimination of the feeding of infected salmon viscera and carcasses to young fish is the best approach toward control of the disease in hatcheries.

Kidney Disease

This disease is not a problem in California at the present time. Although the disease was first reported in 1935, the causative organism has only recently been identified as belonging to the genus *Corynebacterium*. The disease is characterized by white boil-like lesions in the kidney, spleen, liver, and other tissues. Kidney disease has been reported from most salmonids on the Pacific Coast. Treatments using sulfonamides provide temporary control. Feeding of infected salmon carcasses and viscera is responsible for some outbreaks.

External Protozoan Diseases

***Trichodina* spp.**

These ciliated protozoans parasitize most salmonids in California. When numerous they can cause serious losses among fingerling trout and even larger fish. *Trichodina* is commonly found on the body surface and gills. Infected fish flash, in an attempt to scratch off the offending parasites. Irregular whitish areas of a superficial nature appear on the body surface and the fins may become frayed. Scales may be loosened and congested areas appear on the skin. *Trichodina* may be controlled by a 1:500 acetic acid dip, or a 1:4,000 bath in formaldehyde for one hour.

***Epistylis* spp.**

These stalked ciliates (Figure 48) are among the most common protozoans on fish in California. They are found most frequently on fingerling rainbow trout. A light infestation is usually of no consequence. When present in large numbers, these protozoans irritate the fish, causing them to flash. At this stage, 1:500 acetic acid dip or a 1:4,000 formaldehyde bath for one hour will control the organism.

***Chilodon* spp.**

These ciliated protozoans are not common in California hatcheries. They have, however, been found on steelhead fingerlings and some warmwater species. Other than flashing and a slight cloudy appearance of the fish, there is little to guide the hatcheryman in diagnosis. Microscopic examination is the best way to diagnose its presence. A 1:500 acetic acid dip or 1:4,000 formaldehyde bath is effective as a control measure.

***Costia* spp.**

These flagellated protozoans are found at most hatcheries in California and, if not controlled by treatment, can cause severe losses among trout and salmon. A microscope is needed for positive identification. A characteristic symptom is a bluish or grayish film on the body and fins. The parasite may be found in the surface film of the body or on the gills. Good results in treatment have been obtained from a 1:500 acetic acid dip or a 1:4,000 formaldehyde bath.

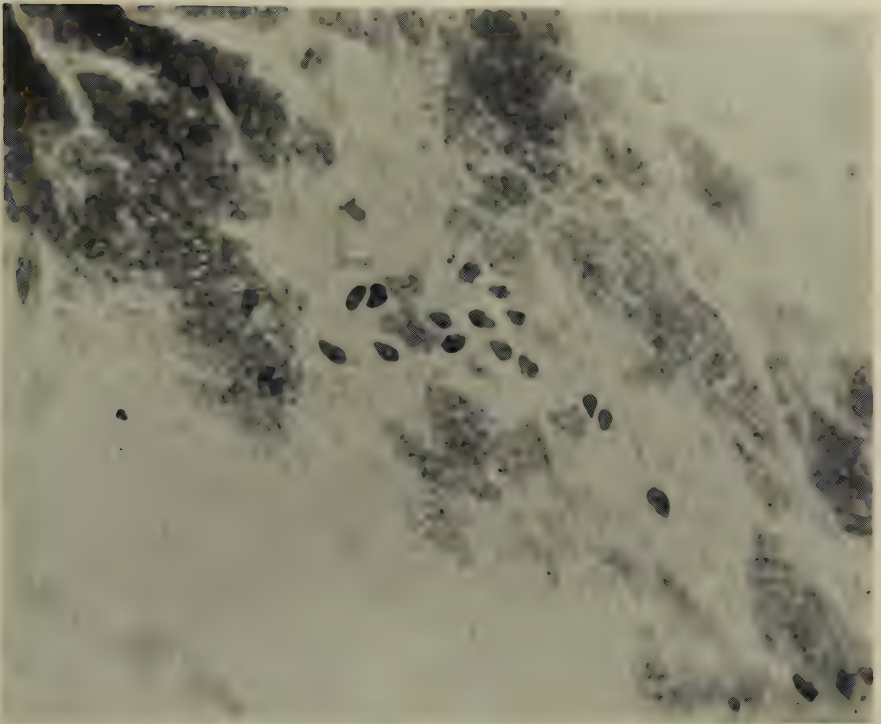


FIGURE 48 *Epistylis* sp. on skin of rainbow trout. Photograph by Harold Wolf, 1958.



FIGURE 49. "Tch" (*Ichthyophthirius multifiliis*) on skin of rainbow trout, a moderate infestation. Photograph by J. H. Wales, 1958.

Ichthyophthirius multifiliis

"Ich" (Figure 49), as this ciliated protozoan is familiarly known to fish culturists, is found on almost all kinds of freshwater fishes. It has on occasion caused serious losses. Warm water and crowding are conducive to the outbreak of "Ich."

Fish infested with this parasite may flash, crowd the water inlet, or later seek slack water areas. When observed closely, the infected fish reveal small, white swellings on the body surface, which may appear roundish. If there are many parasites they may be crowded together sufficiently to present irregular raised patches. When single parasites are observed on the gills, they may appear more oval-shaped than round. Positive identification requires a microscopic examination.

"Ich" has a complicated life cycle. The free-swimming stage may be controlled by a 1:4,000 one-hour formaldehyde treatment. The parasitic stage, which is imbedded in the superficial layer of the skin, resists any known treatment which does not kill the fish. Because the stages on the fish mature and leave the fish at various intervals, it would be necessary to treat for the free-swimming stages at such frequent intervals that this method is impractical, from the standpoint of the fish's ability to stand repeated treatments, and because of the time involved.

One of the best methods for controlling this parasite is to place the infected fish in shallow, swiftly moving water, not allowing the dead fish to accumulate, and sweeping the pond bottoms daily if conditions permit. This method removes the parasites as they leave the fish. The encysted form may remain on the fish for a period of 10 days to 5 weeks, depending on the water temperature. The warmer the water, the shorter it remains on the fish. If clean fish are to be put into a pond which contained fish that had the "Ich", it is best to allow the pond to dry out for several days. If this is not possible, sterilization of the pond with formaldehyde should suffice.

Miscellaneous External Parasites

Copepods

Two copepod genera are of importance in California: *Salmincola* and *Lernaea*.

Salmincola edwardsii

This copepod (Figure 50) has been found mainly on rainbow trout and steelhead. Only on occasion has it been found on other species of salmonids. This parasite has a complicated life cycle. Adults are found on the gills and axillary regions for the most part. Sometimes they may also be found in the mouth. A heavy infestation debilitates the fish, provides a route for secondary infections, and when on the gills makes respiration more difficult. Eggs may be seen attached to the adult copepod or are sometimes found free in the water with free-swimming larvae. The free-swimming larvae become permanently attached to a fish and mature; the cycle is then repeated.

The adult is very resistant to chemicals, and to date no method which will kill it without also killing the fish has been developed. The free-swimming stages are reported to be killed by strong salt solutions, using 1:6,000 formaldehyde for one hour and by treating with concen-

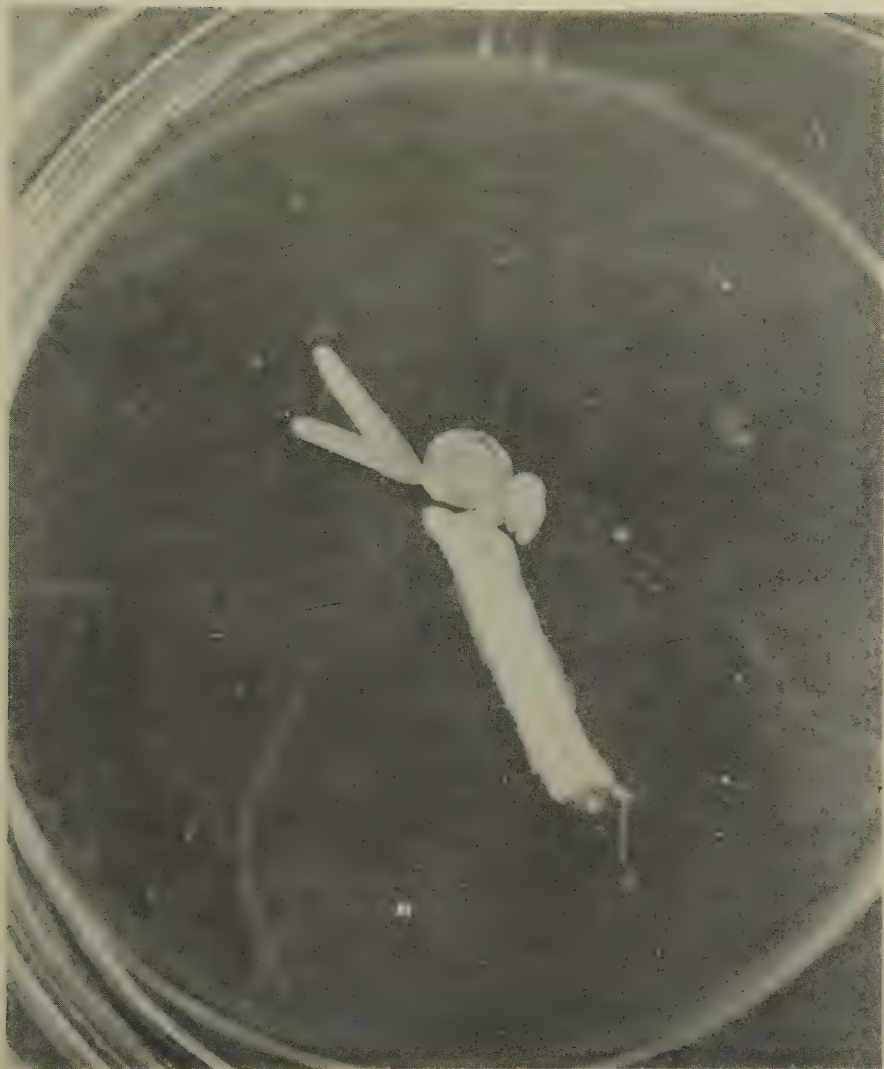


FIGURE 50. Adult copepod (*Salmincola edwardsii*) attached to a gill filament.
Photograph by J. H. Wales, 1958.

trations of from 1:10,000,000 to 1:40,000,000 Lindane. Since the adult copepod may remain alive on a fish for two months or more, treatments to kill free-swimming stages are not effective. Partial control may be effected by keeping infected fish in swiftly moving water.

Lernaea carassii

This copepod, commonly called "anchor worm" (Figure 51), has not been a problem in California hatcheries, although it is seen on a great variety of wild fish. It may occur at the base of the fins or scattered about the body surface. Occasionally it penetrates the eye and causes blindness. It is likely that the methods of controlling *Salmincola* would be effective in controlling *Lernaea*.

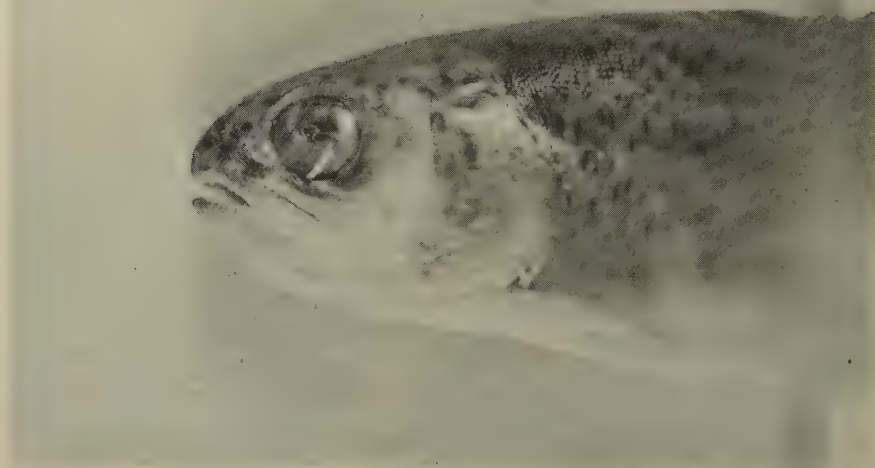


FIGURE 51. Anchor parasite (*Lernaea carassii*) attached to eye and near gill cover. Photograph by Harold Wolf, 1958.

Parasitic Worm

Gyrodactylus elegans

“Gyros” are small worms which infest all species of salmonids reared in California hatcheries (Figure 52). These parasites may be seen with the unaided eye, but a microscope reveals them clearly. Fish infested with “gyros” will flash and, when heavily parasitized, show frayed fins. Successful treatments have consisted of 1:500 acetic acid dips or 1:4,000 formaldehyde treatments.

Fungus

Saprolegnia parasitica

Several genera of fungi have been reported to attack fish and fish eggs. *Saprolegnia parasitica* is the species of importance in California. *Saprolegnia* is generally a secondary invader. Injuries or wounds caused by external parasites usually provide the initial site for infection. The fungus usually presents a grayish-white, furry appearance. Fish affected with fungus may be dipped in a 1:15,000 malachite green solution for 10 to 30 seconds with beneficial results. Salmonid eggs, when threatened by fungus, may also be treated with malachite green as described in the section on treatments.

Hexamitus salmonis

Internal Protozoan Diseases

This flagellated protozoan (Figure 53), best known to fish culturists as octomitus, is found in the intestines of trout and salmon. This organ-



FIGURE 52. *Gyrodactylus elegans*, a parasitic worm, attached to skin by posterior hooks. Photograph by J. H. Wales, 1958.

ism is not believed to cause serious losses. In fact, the opinion is growing that its presence does not indicate a serious condition.

It may be found in healthy, well-formed fingerlings as well as in thin or pinheaded ones. The only sure method of determining the presence of *Hexamitus* is by microscopic examination of the intestinal contents.

Recommended treatment has consisted of adding calomel to the feed for two to four days. The recommended dosages vary from 0.05 to 2.0 percent calomel added to the diet. Calomel can be toxic to fish and in recent years 0.2 percent carbarsone in the diet has been used with good results. Carbarsone is reportedly not toxic to fish at this level.



FIGURE 53. *Hexamitus salmonis* (*Octomitus*), as seen in the intestinal contents under dark-field observation. Photograph by Harold Wolf, 1958.

Cryptobia borreli

Cryptobia borreli, a blood-inhabiting flagellate (Figure 54), has been found in California in salmonids, suckers (*Catostomus*), and sculpins (*Cottus*). The protozoan is transmitted from one fish to another by leeches. This parasite has caused considerable trouble among rainbow trout brood fish. The kidneys' function is upset and infected fish often are anemic, develop popeye, and contain fluid in the body cavity.

Positive diagnosis requires microscopic examination and identification of the protozoan. In very heavy infections the protozoan may be found not only in the blood but beneath the scales and between the muscle



FIGURE 54. *Cryptobia borreli*, a flagellated protozoan found in the blood of salmonids and other fish. Photograph by Harold Wolf, 1958.

segments. No satisfactory method for treating this parasite is known at the present time.

Ceratomyxa shasta

Myxosporidian protozoa are common parasites of fish. Most of them do not cause serious losses among hatchery populations. *Ceratomyxa shasta* (Figure 55), however, has caused very serious losses among rainbow and steelhead at one California hatchery. This parasite invades virtually every tissue in the fish's body, causing great damage and destruction to the tissues. The disease may be transmitted directly from fish to fish by the ingestion of infective spores liberated from infected fish.

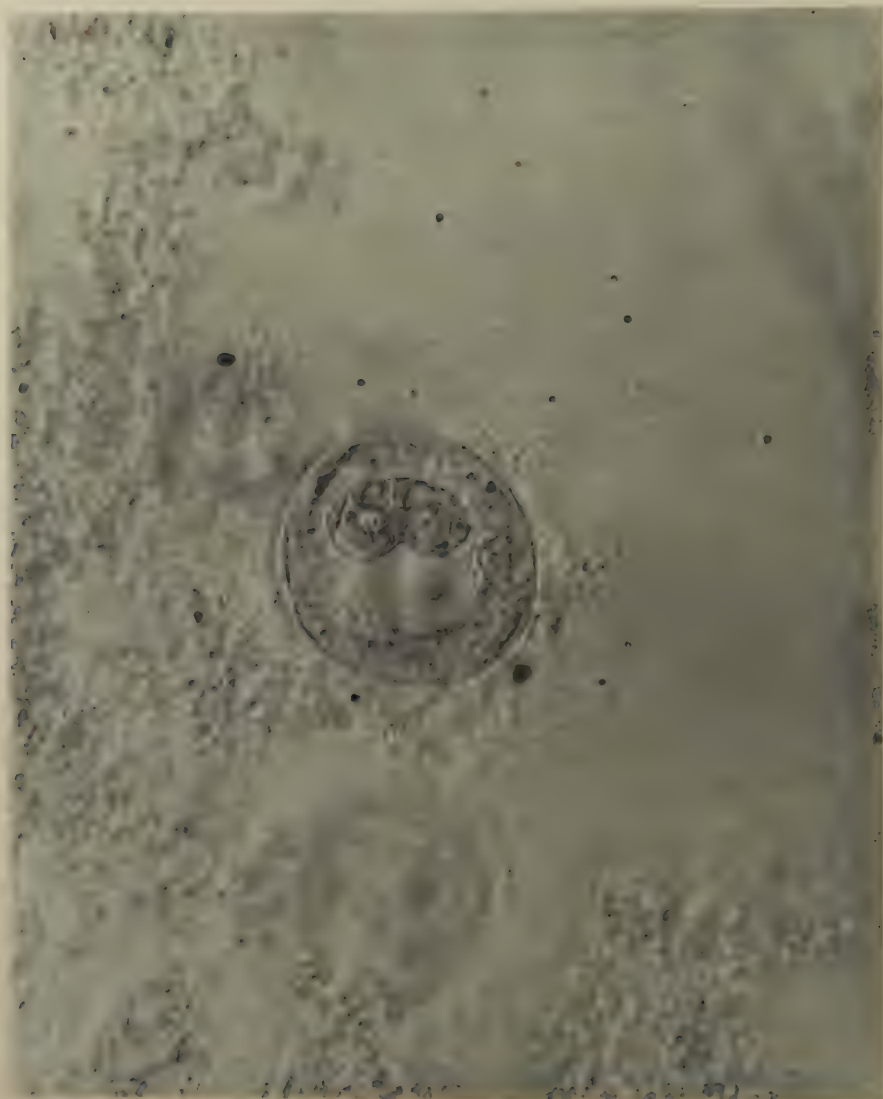


FIGURE 55. The myxosporidian protozoan *Ceratomyxa shasta*. A developing stage showing a mature spore within. Photograph by Harold Wolf, 1958.

This organism is a good example of host specificity. Only rainbow trout and steelhead have been found to be susceptible. Brown trout, brook trout, and some silver salmon, when reared among infected rainbow trout, showed no sign of the parasite. No method of treating with drugs or chemicals to control this parasite is presently known.

Parasitic Worm

Miscellaneous Internal Parasites

Sanguinicola davisi

This trematode worm has on occasion contributed to serious losses among hatchery-reared rainbow (including kamloops) and cutthroat



FIGURE 56. External appearance of fish infected with *Ceratomyxa shasta*. Note the tremendously swollen abdominal region. Photograph by Harold Wolf, 1958.

trout. Its distribution is coincident with the snail *Oxytrema circumlin-eata*, which serves as the intermediate host for the worms. The adult worm lives in the gill arteries. It lays eggs which lodge and develop in the gill capillaries. The eggs develop to the miracidium state and then leave the fish. The miracidia swim about until they find the appropriate snail host. A miracidium penetrates a snail and then undergoes changes and reproduces through a complicated cycle which gives rise to cercariae which leave the snail and swim about in the water until they find a fish. A cercaria penetrates a fish and makes its way to the gill artery, where it undergoes changes into the adult form; the cycle is then repeated. To date no drugs or chemicals which can control this parasite have been found.

The best control method is believed to consist of the eradication of the snails and fish, which provide a reservoir of infection, from the hatchery water supply.

Fungus

Dermocystidium salmonis

This fungus has been found in king salmon, steelhead, and rainbow trout. On one occasion it was associated with a severe die-off in catchable-size rainbow trout. The fungus forms pseudocysts in the gills of the afflicted fish. These cysts superficially resemble "Ich". Only a microscopic examination can assure a positive diagnosis. When the cyst-like structures mature they appear to rupture, releasing the contents.

The cyst-like structure consists of loosely compressed gill tissue cells. Quite often the spores within are mixed with various kinds of bacteria, which are probably secondary invaders.

Virus Diseases

The literature on fish diseases contains many references to investigations of virus diseases.

One virus disease of importance to fish culturists occurs among kokanee and sockeye salmon. This disease takes its greatest toll among fingerling fish. Infected fish are generally weak, and hemorrhaged areas may occur at the base of the fins or in the isthmus. The abdomen may be swollen. The stomach is distended and filled with a milky fluid. The intestine is inflamed and contains a straw-colored, watery fluid. Fish surviving early stages of the outbreak may show spinal deformities.

Diagnosis of a virus disease is complicated. One method is to take material from infected fish, grind it, and pass it through a bacteria-proof filter. The bacteria-free filtrate is inoculated into healthy fish. If such inoculated fish come down with the same symptoms and losses, it is good evidence of the virus nature of the disease.

No drugs or chemicals of value in treating kokanee and sockeye salmon for virus disease have been reported. However, it has been fairly well demonstrated that adult sockeye returning to spawn may carry the virus. When their carcasses and viscera were removed from the diet, the disease was virtually eliminated.

Pancreatic Necrosis

Another disease of possible virus origin is infectious pancreatic necrosis. This disease is considered by some to be identical with a disease previously called acute catarrhal enteritis. It infects fingerlings, especially brook trout, although it has been reported in rainbow, brown, and cutthroat trout, and Atlantic salmon (*Salmo salar*).

Infected fish may whirl or swim in a horizontal spiraling manner. The stomach and anterior intestine are empty of food, distended, and filled with a thick, clear or whitish, mucous material. The spleen and liver may be colorless.

Final diagnosis of this disease depends on microscopic examination of prepared tissues and employment of techniques similar to those used in the diagnosis of sockeye salmon virus disease.

No chemotherapeutic methods for controlling this disease are known. It is considered to be highly contagious, so strict sanitation is necessary to prevent its spread.

METHODS OF TREATMENT

Dip Method

In this method a strong solution is used for a relatively short period. Dip treatments are best carried out in wooden tubs or boxes. Metal tubs are often attacked by chemicals and products formed or liberated may be toxic to fish. A wooden tub of about 12-gallon capacity is recommended. Ten gallons of water is carefully measured into the tub and the required amount of chemical is added and mixed in. A net with enough bag to allow the fish to be entirely covered by the solution is used. The fish are netted, surplus water is allowed to drain off, and the

net containing the fish is placed in the solution. The lip of the net should not be submerged, to prevent fish from escaping into the tub. When the time is up the net is raised, surplus solution is allowed to drain back into the tub, and the fish are placed in fresh water.

It is important that treated fish be returned to troughs or tanks that have been cleaned or preferably disinfected. Treated fish should never be returned to troughs, tanks, or ponds which derive their water from sources that contain diseased fish.

Bath Method (Prolonged Dip)

In this manner of treatment a weaker concentration is used for a longer period than in the dip method. It is often carried out in troughs and may be used in tanks, ponds, and flumes where the water may be turned off and the volume determined. When the desired volume is reached, the water is turned off and the system is checked for leaks. If the water level remains stable and the volume has been determined, the proper amount of chemical is added and mixed in. The length of treatment will vary with the water temperature, condition of the fish, and the chemical being used. In many cases it is necessary to aerate the water during treatment.

Aeration may be accomplished in several ways. The hand aerator is a primitive but satisfactory method for aerating troughs or small tanks. It is not suitable for ponds or flumes of large size or volume. Gasoline or electrically-operated air compressors, fitted with rubber hoses and aerator stones, have been used successfully in troughs and small tanks.

One of the best methods of aerating a large pond or tank is to use a motor-driven pump which will recirculate the water. The intake hose is placed at one end of the pond and the discharge hose at the other end. The discharge hose is directed at the side or end of the pond, thus breaking up the flow and aerating the water.

Flush Treatment

This method has become very popular, due to its simplicity. It may be used in raceways, tanks, and troughs. Without removing the fish, a measured amount of a chemical solution is added at the inlet and allowed to flush through the pond, tank, or trough. The amount of chemical, rate of flow, and depth of water must be established on an individual hatchery basis by trial and error before large-scale flush treatment methods can be employed.

A stock solution of copper sulfate, varying from $\frac{1}{2}$ to $1\frac{1}{2}$ pounds per gallon of water, has been flushed through standard raceway ponds with a flow of 1 to 3 c.f.s. and found to control bacterial gill disease. "Gyros" have been controlled by flushing $\frac{1}{2}$ to $1\frac{1}{2}$ gallons of acetic acid through ponds with a flow of 1 to 3 c.f.s.

It has been found that lowering the water level in raceways evens out the flow and eliminates dead water spots, thus insuring a better distribution of the treating agent.

Disinfection

Occasionally the need for disinfection of equipment arises. One of the best and cheapest disinfectants is chlorine. A solution of 200 parts per million will sterilize equipment in 60 minutes. A solution of 100

p.p.m. will require several hours for complete sterilization. Chlorine concentration is reduced by the presence of organic material such as mud, slime, and plant material. Therefore, for full effectiveness, it is necessary to clean thoroughly equipment to be exposed to the chlorine solution. A chlorine solution will lose its strength by exposure, so it is necessary to add more chlorine or make up fresh solutions. Containers used in sterilizing small pieces of equipment should be painted with asphaltum before being used.

Chlorine is toxic to trout. If troughs, tanks, or ponds are disinfected, the chlorine must be neutralized before it is allowed to pass undiluted through waters containing concentrated numbers of fish.

One gallon of 200 p.p.m. chlorine solution may be neutralized by adding 5.6 grams of sodium thiosulfate. Neutralization may be determined by the use of starch-iodide chlorine test papers (obtainable from LaMotte Chemical Products Company) or by the use of orthotolidine solution. A few drops of orthotolidine are added to a sample of the solution to be tested. If the sample turns a brown color, chlorine is present. Absence of color means that the chlorine has been neutralized.

Chlorine may be obtained as sodium hypochlorite in either liquid or powdered form. The latter is the more stable of the two, though more expensive.

The amount of chlorine to be added to water in making up a predetermined solution is based on the percentage of available chlorine in the product used. As an example, HTH powder may contain either 15, 50, or 65 percent available chlorine. It would, therefore, require the following amounts to make a 200 parts per million solution.

Two ounces of 15 percent available chlorine HTH powder to 10½ gallons of water.

One ounce of 50 percent available chlorine HTH powder to 18 gallons of water.

One ounce of 65 percent available chlorine HTH powder to 23¼ gallons of water.

Drug and Feed Mixing

Treatment of some diseases, such as columnaris, ulcer disease, and furunculosis, requires the feeding of drugs. This is accomplished by mixing the drug with the feed. The amount of drug to be fed is relatively small and thorough mixing is necessary to insure proper distribution. Fish should be hungry before they are administered drugs; it may be necessary to eliminate a feeding to insure that the drugged food is taken readily.

Food that is to have a drug added should be run through the grinder once or twice to reduce it to a consistency which can be mixed easily. Then, one or two pounds of food are put through the grinder and part of the drug is added to this portion and mixed in thoroughly with a spoon. Another few pounds of food are run through the grinder and more drug is added and mixed in with a spoon. This process is continued until the amount of drug necessary for one bucket of food has been added and mixed. The entire bucketful is then reground for further mixing and is ready to be fed.

With the development of dry feeds it has been possible to buy feed containing the drug of choice. In most cases it is necessary to have the food containing the drug custom-milled. Fish of different sizes require

varying amounts of feed and drug, and custom milling is necessary in order to get the proper dosage.

For example, 100 pounds of trout might require food amounting to 5 percent of their body weight. Thus, 5 pounds of feed would contain 10 grams of drug. Another 100 pounds of different sized trout might require 3 percent of their body weight of feed. Thus, for the same dosage they should get 10 grams of drug in 3 pounds of feed.

CHEMICALS AND THEIR USES

Salt

Salt is one of the oldest and most commonly used chemicals in the treatment of diseases of trout. Its therapeutic value is based on two of its actions. (1) It causes the mucus covering the fish's skin to be sloughed off, thereby removing organisms which are loosely attached to the mucus. (2) It raises the specific gravity of the water and changes the osmotic pressure which, in turn, causes many external parasites to burst.

Salt seems to exert the best action when used as a 3 percent solution. The length of the bath varies with the water temperature and condition of the fish. *Costia*, *Ichthyophthirius*, *Chilodon*, *Trichodina*, and *Epistylis* are all external protozoans which may be controlled in varying degrees by salt treatments. Usually two or three treatments are necessary.

Copper Sulfate

Copper sulfate, or bluestone, is another old stand-by. Properly used, it provides a most effective treatment. It is often used as a dip at a 1:2,000 concentration for one to two minutes. It may be necessary to add a small amount of acetic acid ($\frac{3}{4}$ ounce) to a 10-gallon tub of the solution in hard waters. The acid prevents the copper sulfate from going out of solution and forming a white precipitate at the bottom of the tub. When the copper sulfate precipitates, part of its beneficial action is lost.

Copper sulfate is useful in controlling external bacteria causing fin rot, tail rot, and gill disease, provided the fish are treated before the bacteria have invaded the deeper tissues. Some external protozoans may also be controlled by copper sulfate; however, other treatments are more satisfactory in controlling these organisms.

Acetic Acid

This acid will eradicate many external parasites in a single treatment when used as a dip of 1:500 for one minute. Heavy infestations may require follow-up treatment.

External protozoans and the worm *Gyrodactylus* are effectively controlled by this treatment. Bacterial infections are not particularly susceptible to acetic acid. Each tub of solution should be aerated at intervals and the solution renewed after five or six batches (50 to 70 ounces per batch) of fish have been dipped. After the third or fourth bath, the immersion time may be increased to one-and-one-half minutes to compensate for dilution.

Formaldehyde (Formalin)

This chemical is used as a prolonged dip (one-half to one hour) in troughs, tanks, and raceway ponds when the water volume can be determined with reasonable accuracy. Because of the duration of the treatment, it may be necessary to aerate the water while the fish are being treated. A concentration of 1:4,000 is best, although a dilution of 1:6,000 may sometimes be satisfactory.

Formaldehyde is most useful in treating for external protozoans. One advantage in using formaldehyde lies in not having to handle the fish; however, in certain types of water it may cause above normal treatment losses. A word of caution to those who have not used formaldehyde is to try it in a single trough a day before treating an entire hatchery, to determine if a significant loss will follow.

Pyridylmercuric Acetate (PMA)

This compound was first used in treating bacterial gill disease in salmon. It has since been used in several hatcheries in California, with varying degrees of success. It is used as a prolonged dip (one hour) and it may be necessary to aerate the water during treatment. It is also important to allow the trough or tank enough time to be thoroughly drained or diluted before feeding. PMA is usually used at a 1:500,000 dilution; however, the activity of PMA increases with a rise in temperature. The manufacturer believes that no concentration need be greater than 1:500,000, although they offer the following schedule for the use of PMA.

Degrees F.	Concentration
32-41 -----	1:250,000
41-50 -----	1:375,000
51-59 -----	1:500,000
60-68 -----	1:750,000
69-77 -----	1:1,000,000

A simple method of handling this chemical is by the use of a 10 percent stock solution. If it is to be used for the first time at a hatchery, it would be best to try it on a limited scale, observing the results a day later. Since this product is variable, each shipment should be tested before general use. Because of reports of toxicity to rainbow trout, it should receive a thorough testing each time it is to be used on this species.

Calomel (Mercurous Chloride)

This compound has been used by fish culturists for the control of *Hexamitus* (formerly called *Octomitus*). Calomel is mixed with the food at a 0.05 percent level and may be fed at one feeding per day on two successive days. Unfortunately, calomel on occasion has caused severe losses and is not as popular as it was at one time.

Carbarsone

This drug is also used in controlling *Hexamitus*. It may be fed in the same manner as calomel, but only at a level of 0.2 percent. Carbarsone in some cases has been quite effective in controlling *Hexamitus* without causing the severe losses that may be encountered with calomel. Its high price is its main disadvantage.

Sulfamerazine

Reports indicate that this drug may be used successfully in combating certain bacterial diseases (furunculosis and ulcer disease). Sulfamerazine is usually mixed in the feed and fed at the rate of 8 to 10 grams of drug per day for every 100 pounds of fish. It is recommended that the drug be fed daily until the mortality stops and then continued for two or three additional days.

In treating brown trout for furunculosis it was found best to use 8 grams of sulfa drugs (5 grams of sulfamerazine plus 3 grams of sulfaguanidine) per 100 pounds of fish.

Sulfomerthiolate

This organic mercurial compound has been used successfully in experimental work for the disinfection of trout eggs during all stages of their development up through the eyed stage. Sulfomerthiolate is especially used in disinfecting eggs that have been exposed to furunculosis. The concentration recommended is 1:5,000. It is best to disinfect eggs either soon after they have become water hardened or after they are eyed, although eggs may be treated during the tender stage if handled carefully. As many as 50,000 eggs may be treated in three gallons of the solution. Two methods used for treating eggs are the following:

1. Dip eggs for 10 minutes in a 1:5,000 solution. The eggs should be moved about every two minutes to insure complete contact with the solution. A wooden, enamel, or asphalt-painted container should be used to hold the solution. Several baskets of eggs may be treated with the same solution if it is well aerated and not more than a few hours old.

2. An entire trough of egg baskets may be treated at one time with the bath method. It is necessary to calculate the amount of water in the trough and to add the amount of sulfomerthiolate required to produce a 1:5,000 concentration. The bath is continued for 10 minutes. During the treatment it is necessary to aerate or recirculate the water. Both the sulfomerthiolate *powder* and *solution* are quickly destroyed by direct sunlight and must be kept shaded at all times.

Acriflavine

If sulfomerthiolate is not available, acriflavine may be used for disinfecting eggs. A concentration of 1:2,000 is recommended. The eggs are held in the treating solution for 20 to 30 minutes. It is also possible to disinfect the eggs with a 10-minute treatment in a 0.185 percent solution.

Malachite Green

This dye is well known to the science of bacteriology for its bactericidal properties. In 1936, it was successfully used in controlling fungus on trout. It was found that a 1:15,000 solution of malachite green used as a 10- to 60-second dip for two or three treatments cleared up fungus infections. Fungus on trout is usually considered a secondary invader and unless the primary cause is controlled, redevelopment of the fungus may occur. It is important that the malachite green specified be of low zinc content.

Malachite green is also used to control fungus on salmonid eggs. Three methods of treating eggs have been developed.

1. The flush method involves the use of a stock solution (1½ ounces malachite green dissolved in one gallon of water). Three ounces of this solution are poured into the head end of the trough. Water inflow is set at six gallons per minute. This process is repeated every other day, although it may be repeated daily if required.

2. The dip method involves the use of a solution of known concentrations and requires the egg baskets to be drained and placed in the dip for varying lengths of time. This method is not used often, since the handling may cause shock to the eggs, with subsequent losses.

3. The prolonged dip method is probably the best, but requires a certain amount of work in setting up and calibrating the equipment to be used. However, any hatchery troubled with a severe fungus condition on eggs may be better off to use this method rather than the others previously mentioned.

This method requires the use of a constant flow siphon which adds malachite green to the water at a 1:200,000 concentration for one hour. Complete details for using this method are given by Burrows (1949).

ANESTHETICS AND THEIR USE

Anesthetics have been used for some time by fisheries workers as an aid in fin clipping, spawn taking, and fish transportation. The degree of anesthesia required for these uses varies. Transportation of fish requires a relatively light anesthesia, whereas a deep anesthesia is best for spawn taking.

A variety of drugs having anesthetic properties have been used. These include cresol, ether, carbon dioxide, chlorotone (chlorbutanol), sodium amytal, methyl pentynol, MS-222 (tricaine methane sulfonate), quinaldine, and urethane (ethyl carbonate). Urethane is no longer used in California because tests with mammals indicate it could be carcinogenic (cancer producing) after prolonged and repeated exposures. For a variety of other reasons, many of the anesthetics mentioned above are no longer in common use. For spawn-taking operations MS-222 (tricaine methane sulfonate) and methyl pentynol have been widely accepted and are in most common use.

MS-222 (Tricaine Methane Sulfonate)

This odorless, water-soluble, drug comes in powdered form. It is non-prescriptive and has a good storage life unless placed in solution. No vehicle is required in making an aqueous solution. The measured amount of powder is simply sprinkled into the water and stirred. It has a safe exposure time in that fish may be left in the solution for a considerable duration. Recovery when placed in fresh water is quite rapid. It may be used in concentrations varying from 1:20,000 to 1:10,000. It has even been used in stronger concentrations without harmful effect. MS-222 may be obtained from Sandoz Pharmaceuticals, Division of Sandoz, Inc., Route 10, Hanover, New Jersey. The cost is \$25 per 100 grams, or \$200 per 1,000 grams.

Methyl Pentynol

Methyl pentynol, a nonprescriptive drug in liquid form, is sufficiently water soluble for use in making an aqueous solution without the use of a vehicle. It has a good storage life. A minor disadvantage is that

TABLE 17
Solution Chart for a Standard California Hatchery Trough

Depth in inches	Gallons	Cubic feet	Cubic inches	Cubic centimeters	Acetic acid 1:500 1- or 2-minute dip		Copper sulfate 1:2,000 1- or 2-minute dip			Formaldehyde 1:4,000 ½ to 1 hour bath		PMA Pyridylmercuric acetate 1:500,000 1 hour bath		
					Ounces	cc.	Ounces*	Grams*	cc. †	Ounces	cc.	Ounces ‡	Grams*	cc. ‡
1	13.29	1.777	3,072	50,340	3.40	100.6	0.88	25.17	211.0	0.43	12.5	0.28	0.1	1.0
2	26.59	3.554	6,144	100,681	6.80	201.2	1.76	50.34	422.0	0.86	25.17	0.56	0.2	2.0
3	39.87	5.331	9,216	151,022	10.20	301.8	2.64	75.52	633.0	1.30	37.75	0.84	0.3	3.0
4	53.16	7.108	12,288	201,363	13.60	402.4	3.52	100.69	844.0	1.73	50.34	1.12	0.4	4.0
5	66.45	8.885	15,360	251,704	17.00	503.0	4.40	125.87	1,055.0	2.17	62.9	1.40	0.5	5.0
6	79.74	10.662	18,432	302,045	20.40	603.6	5.28	151.04	1,226.0	2.60	75.5	1.68	0.6	6.0
7	93.03	12.439	21,504	352,386	23.80	704.2	6.16	176.21	1,477.0	3.04	88.0	1.96	0.7	7.0
8	106.32	14.216	24,576	402,726	27.20	804.8	7.04	201.39	1,688.0	3.47	100.68	2.24	0.8	8.0

* Dry weight.

† Solution of one pound of copper sulfate dissolved in one gallon of water.

‡ 10 percent PMA solution (10 grams PMA dissolved in 100 cc. of water).

TABLE 18
Dip Treatments

Acetic acid 1:500			Copper sulfate 1:2,000				
Ounces	Cubic centimeters	Gallons of water	Grams*	Ounces*	Ounces†	Cubic centimeters†	Gallons of water
0.27	7.0	1	1.89	0.067	0.53	15.88	1
1.35	37.8	5	9.46	0.33	2.68	79.40	5
2.70	75.7	10	18.92	0.67	5.36	158.80	10
4.05	113.5	15	28.38	1.01	8.05	238.20	15
5.40	151.4	20	37.84	1.35	10.73	317.60	20

* Dry weight.

† Solution of one pound of copper sulfate dissolved in one gallon of water.

TABLE 19
Salt Solution Chart for a Standard California Trough

Depth in inches*	Percentage	Salt (pounds)	Salt (grams)
3-----	1	3.30	1,510
3-----	2	6.60	3,020
3-----	3	9.90	4,530
4-----	1	4.41	2,013
4-----	2	8.82	4,027
4-----	3	13.23	6,040
5-----	1	5.54	2,517
5-----	2	11.09	5,034
5-----	3	16.64	7,551
6-----	1	6.65	3,020
6-----	2	13.31	6,040
6-----	3	19.97	9,061

* Depth measured at center of trough.

TABLE 20
Food Treatment for Hexamitus (Oclomitus)

Calomel 0.05 percent (1:2,000) in food			Carbarsone 0.2 percent in food		
Avoirdupois ounces	Grams	Food in pounds	Avoirdupois ounces	Grams	Food in pounds
0.04-----	1.13	5	0.03-----	0.90	1
0.08-----	2.26	10	0.16-----	4.54	5
0.12-----	3.40	15	0.32-----	9.07	10
0.16-----	4.53	20	0.48-----	13.60	15
0.24-----	6.8	30	0.96-----	27.28	30
0.32-----	9.0	40	1.28-----	36.29	40
0.40-----	11.34	50	1.60-----	45.36	50
0.80-----	22.68	100	3.20-----	90.72	100

a solution containing methyl pentynol will foam on agitation and the addition of an antifoam agent may become necessary.

The amounts needed for deep anesthesia vary from 2 to 10 cc. of methyl pentynol per gallon of water. This product is available from

Air Reduction Chemical Company, 150 East 42nd Street, New York 17, New York. The price varies from \$2 to \$3 per pound, depending on the amount purchased.

Quinaldine

Quinaldine is among the newer anesthetics used in fisheries work. It is reportedly suitable for use in marking fish or in other work involving gentle handling. Its use as an aid in spawning has not yet been reported. It comes in liquid form, is nonprescriptive, and is sufficiently water soluble for fisheries work. Acetone may be used as a vehicle with quinaldine to make aqueous solutions, although this is not necessary. Concentrations used have ranged from 5 to 12 p.p.m. Some species have been exposed to concentrations up to 20 p.p.m. without ill effects. Quinaldine practical grade may be obtained from chemical supply houses for approximately \$11 per pound. It is manufactured by Matheson, Coleman and Bell, Norwood (Cincinnati), Ohio.

Those who use anesthetics for the first time or are trying new ones should exercise care until the fish's actions and survival are understood. Each new condition, such as a changed water temperature, species of fish, size of fish, or concentration of anesthetic, merits a careful trial before full-scale use is adopted.

NETS AND SEINES

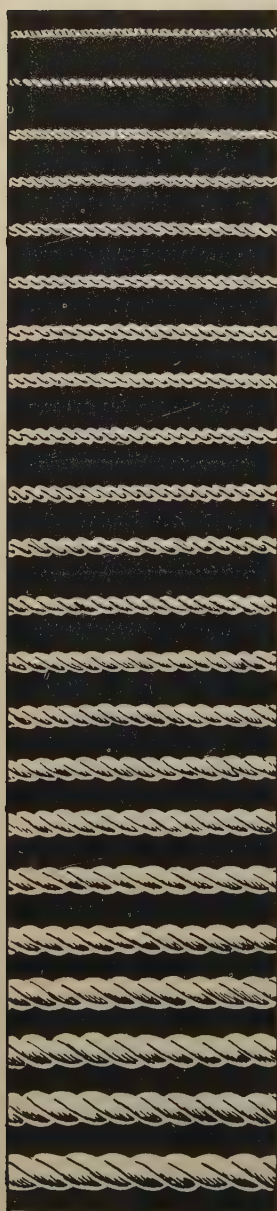
The capture of fish with nets or seines has been practiced by fishermen for centuries. Early fish nets were woven of raffia, hemp, or reed grasses. Cotton nets have been used for many years. At present, however, nets woven of nylon twine are perhaps in greatest use. There are many known methods of weaving or mending nets throughout the world, but all are basically similar. Most nets are made by machine but their mending must be done by hand; this will probably always remain a part of the fisherman's work.

Net mending is an age old art and proficiency in this field is attained only after considerable instruction and practice. Fish culturists are not expected to be highly skilled in the art of net mending. Minor repairing of nets used at hatcheries, though, is part of the hatcheryman's duties and some knowledge of net mending will be useful. A recommended reference and guide to net mending can be obtained by writing to the U. S. Fish and Wildlife Service, Washington, D. C. The publication is "Methods of Net Mending", Fishery Leaflet No. 241 (Knake, 1947).

Nets are hung on lines consisting of either manila hemp or cotton rope. The upper or float line secures the floats, which cause the line to float and the net to hang in a vertical position in the water. The lower or lead line is equipped with weights which sink the lower portion of the net. Net floats are made of cedar, cork, glass, plastic, or aluminum. Cedar or cork floats are in common use. Weights for the lead line are nearly always made of lead. The action of a net in the water can be regulated, to some extent, by the size and number of floats or weights used. Nets which are drifted in the water have a greater number of floats than those which are still-fished or are drawn through the water.

Nets are woven of seine twine, which comes in a variety of sizes (Figure 57A) and in three general types: soft laid, medium laid, and

hard laid. Nets of soft-laid twine normally do not have the lasting qualities of nets woven of medium- or hard-laid twine. To minimize injury to fish by the knots in the net, dip nets for handling brood stock should be of soft-laid twine. Nets for seining fish in ponds and other hatchery use, however, are of medium- or hard-laid twine.



Twine sizes

A

6

9

12

15

18

21

24

27

30

36

42

48

54

60

72

84

96

108

120

132

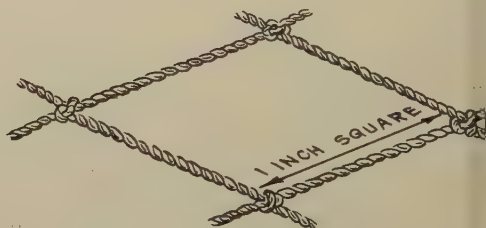
138

144

FIGURE 57. Net and twine nomenclature (actual size).

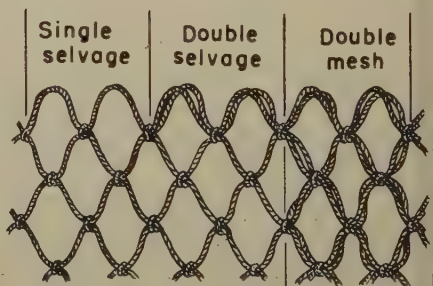


Stretched mesh



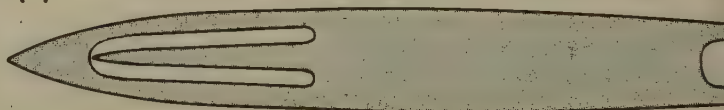
Square mesh

B



Net edges

C



D

Seine needle

Nets are measured by the mesh, either stretched mesh or square mesh (Figure 57B). Considerable latitude is allowed in the size of twine used. The smaller the mesh, the finer the twine.

When ordering nets, it is always necessary that the following information be given: mesh, square or stretched (Figure 57B); twine, size (Figure 57A); twine, soft-, medium-, or hard-laid; length in meshes, depth in meshes; selvage, single or double (Figure 57C); floats, size and spacing; weights, size and spacing; lines, size rope for both float and lead lines.

Nets, like all gear, will wear out and some losses cannot be avoided. Proper care and treatment, however, will greatly prolong the life of a net. It should be washed, spread out, and dried in the shade each time after use, then rolled up and stored where the sun will not shine on it. The agent most destructive to nets kept in water for considerable periods is a microscopic form of life that digests (eats) cotton or similar material. This agent is most active when a damp net is piled in a heap during warm weather.

Remember, nets should always be washed, spread out, and dried immediately after use. It is well recognized that the life of a net can be prolonged greatly if it is properly and periodically treated.

Treatment of Nets

There are several recommended methods of treating nets. They are sometimes referred to as tanning or barking, depending on the type of chemicals used. Due to the availability of materials required and ease of application, the copper oleate method is one of the most popular in use today. The procedure is as follows:

Materials

Brown laundry soap—about $1\frac{1}{2}$ pounds

White laundry soap—about $1\frac{1}{2}$ pounds

Dissolve soaps in 10 gallons of *hot* water.

Copper sulfate (CuSO_4)— $1\frac{1}{2}$ pounds

Dissolve copper sulfate in 10 gallons of *cold* water.

Method. (1) Place netting in hot soap solution and agitate for about one-half minute, (2) shake off excess soap solution, then place in *cold* copper sulfate solution and agitate for about one-half minute, and (3) hang netting to dry, well spread out.

This method is suggested as an inexpensive treatment for net material. It has the advantage of using easily obtainable materials. All new nets should be treated by this or some other method before being used. All nets should be treated at least monthly while in use and treated before being stored. Used nets should be cleaned thoroughly before treatment.

For float and lead lines, manila fiber rope spun and twisted so as to provide maximum strength and service and not kink after it is wet should be used. Fish net rope is available at most houses dealing in netting and allied materials and is available in sizes shown in Table 21.

Dip Nets

Dip nets are usually made to meet individual requirements and consist of a metal frame on which the dip net bag is hung and a hard wooden handle. Insofar as it is known; dip net frames suitable for

TABLE 21
Manila Rope, Fine Thread

Diameter	Thread	Feet per pound	Tensile strength in pounds
3/16 inch.....	6 fine	66.6	450
1/4 inch.....	6	50.0	600
5/16 inch.....	9	34.5	1,000
3/8 inch.....	12	24.4	1,350
7/16 inch.....	15	19.0	1,750
15/32 inch.....	18	16.0	2,250
1/2 inch.....	21	13.3	2,650
17/32 inch.....	24	12.0	3,050
9/16 inch.....	27	9.61	3,450
5/8 inch.....	30	7.25	4,400
3/4 inch.....	33	6.00	5,400
25/32 inch.....	36	5.75	5,950
13/16 inch.....	39	5.13	6,500
7/8 inch.....	45	4.45	7,700
1 inch.....	54	3.71	9,000

hatchery use are not commercially manufactured and usually the frames are fabricated of metal rod or heavy wire and attached to a handle suitable for the job. In selecting dip net handles, it is well to consult a wholesale hardware catalog in which a variety of suitable wooden handles with metal-end ferrules can be found. Figure 58 shows two types of dip net frames suitable for hatchery use.

Dip net bags are essentially seine material and require the same treatment and care as seines. They are usually woven in circular shape, with either square or round closed bottom.

Descriptions of dip net bags suitable for use with dip net frames illustrated in Figure 58 follow:

For handling brood fish: Dip net bag—circular, 2-inch stretched mesh, 44 meshes circumference, 14 meshes deep, no. 32 soft-laid twine, square bottom, selvage double stitched.

For handling catchables: Dip net bag—circular, 1-inch stretched mesh, 60 meshes circumference, 20 meshes deep, no. 9 medium-laid twine, square bottom, selvage double stitched.

At this writing, seines, nets, and allied materials are available from:

The Linen Thread Company, Inc. (cotton)
116 New Montgomery Street
San Francisco 5, California

R. J. Ederer Company (cotton)
540 Orleans Street
Chicago, Illinois

Forelle Fish Netting Company (nylon)
1030 South First Street
Milwaukee, Wisconsin

In nearly every instance the seine webbing will wear out much before the float and lead lines, and when the lines become unusable the floats and leads themselves remain in good condition. For this reason some hatchery managers obtain seine webbing of a size to meet their require-

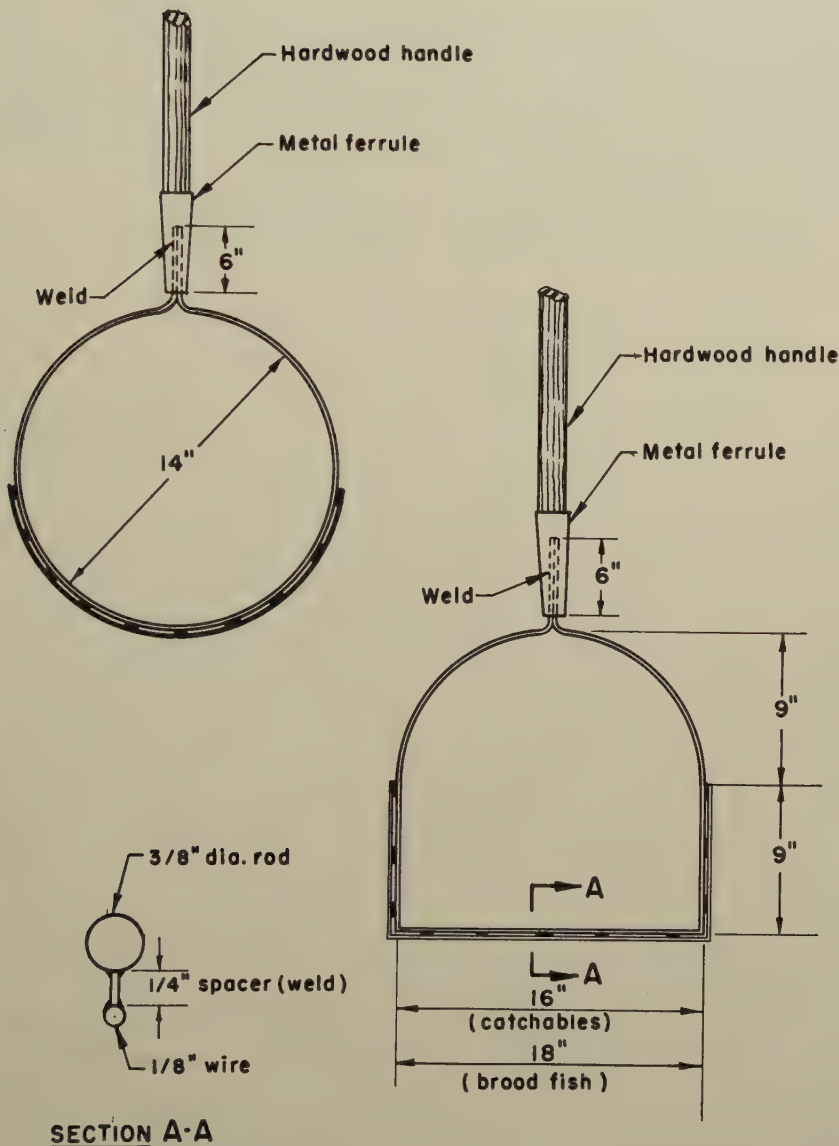


FIGURE 58. Dip net frames.

ments and then make up or hang their own seines, reusing the old rope, floats, and leads. By doing this the cost of hatchery seines is somewhat reduced. Seine material, rope, floats, and leads, or complete seines made to order are available.

For seining catchable trout in the standard California raceway pond, a seine approximately 30 feet long by 6 feet deep is recommended. A mistake often made in ordering seines is specifying a seine too short and not deep enough to allow it to bag properly when being fished.

A description of a seine which has proven quite satisfactory at California hatcheries is as follows: One-half inch stretched mesh, no. 6 medium-laid cotton twine, double selvage, 720 meshes (30 feet) long. 264 meshes (6 feet) deep, hung with $\frac{1}{4}$ -inch cotton rope float and lead lines, cork floats to be 3 inches in diameter by 2 inches thick and spaced 12 inches apart. Lead line to have 2-ounce wrap around lead weights spaced 8 inches apart. (The same description may be used for $\frac{3}{4}$ -inch stretched mesh seine.)

Approximate yardage of cotton and nylon seine twine used in weaving and repairing nets and seines is given in Table 22.

TABLE 22
Seine Twine Sizes

Medium-Laid Cotton Seine Twine			
Size twine	Feet per pound	Size twine	Feet per pound
6.....	3,300	48.....	390
9.....	2,100	54.....	345
12.....	1,600	60.....	270
15.....	1,250	72.....	220
18.....	1,050	84.....	190
21.....	900	96.....	170
24.....	780	108.....	150
27.....	690	120.....	130
30.....	620	132.....	120
36.....	550	138.....	115
42.....	450	144.....	110

Twisted Filament Nylon Twine		
Size	Pound test	Packaged
No. 6.....	42	$\frac{1}{4}$ -pound tubes
No. 60.....	395	1-pound tubes
3/16 inch.....	1,100	50- and 100-foot hanks

Braided Filament Nylon Twine		
Size	Pound test	Packaged
No. 993.....	135	50-foot connected hanks
1/8 inch.....	450	50-foot connected hanks
3/16 inch.....	750	50-foot connected hanks

THE CLASSIFICATION OF FISHES

All known living things have been given scientific names and classified by categories to show their evolutionary relationships.

The fisheries manager will do well to master an understanding of the classification of fishes generally, and particularly to know the relationships and names of the fishes with which he deals. Such an understanding will help him in his discussions with the interested public, and

will enable him to more competently handle various problems that may arise.

The basic categories used to classify all animals (and plants), listed in order from the smallest unit to the largest grouping, are as follows: species, genus, family, order, class, and phylum.

A species may be defined as a group of interbreeding individuals not ordinarily interbreeding with another such group; a systematic unit including geographic races and varieties, and included in a genus. A species may include two or more subspecies.

The scientific name of every species or "kind" of animal consists of two parts, first the name of the genus and second the name of the species. Thus, the scientific name of the rainbow trout is *Salmo gairdnerii*, and it is a member of the Family Salmonidae, which includes all of the trouts, salmons, and chars. The scientific name is always written in italics. The name of the individual who described the species follows the scientific name (without italics), but is often omitted in nontechnical publications.

Ichthyologists are by no means agreed upon the proper arrangement of the various categories of classification for fishes. As new facts, which lead to new concepts of relationships, are uncovered, changes are made in names and in the grouping of the various categories of classification.

In accordance with general custom, in keys and lists the most ancient, simplest, or most primitive types are listed first, followed by a sequence ending with the most highly specialized, recent forms.

In addition to their scientific names, most game fishes and some non-game ones have been given common names. Scientific names are given and recognized only according to established rules of nomenclature, but anyone is "free" to call a fish by any common name he chooses. Thus, although the scientific names of fishes have varied to some extent as new facts have been uncovered, common names have varied even more widely, depending upon local usage, appearance based on habitat, sexual development, or sexual differences, superficial or supposed resemblance to other forms, or merely the whim of the individual. For example, other common names that have been used for the king salmon are black salmon (applied to individuals that have become dark because of long presence in fresh water), chub salmon (applied to young males), dog salmon or hookbill (applied to males with hooked snouts), silver salmon (applied to young fish fresh from the ocean in the Sacramento River system), chinook salmon, spring salmon, quinnat salmon, and tyee salmon.

In recent years serious attempts have been made by state authorities and national groups, notably the American Fisheries Society, the Society of Ichthyologists and Herpetologists, and the Outdoor Writers Association of America, to establish "official" common names for at least the principal food and game fishes of the United States. The most recent such list for California freshwater and anadromous fishes is that by Shapovalov, Dill, and Cordone (1959).

"Keys" to all the freshwater and anadromous fishes, which will enable the individual to identify a specimen in hand in accordance with differentiating characters, are now also available (Kimsey and Fisk, 1958). Those interested particularly in the relationships and

characteristics of the trouts and salmons of California are referred to the publications by Shapovalov (1947) and Wales (1957).

A complete list of the common and scientific names of the salmons and trouts of California follows. Forms which have been introduced into California waters are denoted by an asterisk (*), and those which are not currently being propagated in the State's hatcheries by a dagger (†).

1. Pink salmon †	-----	<i>Oncorhynchus gorbuscha</i>
2. Chum salmon †	-----	<i>Oncorhynchus keta</i>
3. Silver salmon	-----	<i>Oncorhynchus kisutch</i>
4. King salmon	-----	<i>Oncorhynchus tshawytscha</i>
5. Sockeye salmon (anadromous form †) ; Kokanee salmon (freshwater form *)	-----	<i>Oncorhynchus nerka</i>
6. Brown trout *	-----	<i>Salmo trutta</i>
7. Coast cutthroat trout	-----	<i>Salmo clarkii clarkii</i>
8. Lahontan cutthroat trout	-----	<i>Salmo clarkii henshawi</i>
9. San Geronio cutthroat trout †	-----	<i>Salmo clarkii evermanni</i>
10. Piute cutthroat trout †	-----	<i>Salmo clarkii seleniris</i>
11. Steelhead rainbow trout	-----	<i>Salmo gairdnerii gairdnerii</i>
12. Kamloops rainbow trout *	-----	<i>Salmo gairdnerii kamloops</i>
13. Shasta rainbow trout	-----	<i>Salmo gairdnerii stonei</i>
14. Kern River rainbow trout †	-----	<i>Salmo gairdnerii gilberti</i>
15. Eagle Lake rainbow trout	-----	<i>Salmo gairdnerii aquilarum</i>
16. Royal silver rainbow trout †	-----	<i>Salmo gairdnerii regalis</i>
17. South Fork of Kern golden trout	-----	<i>Salmo aguabonita aguabonita</i>
18. Little Kern golden trout †	-----	<i>Salmo aguabonita whitei</i>
19. Eastern brook trout *	-----	<i>Salvelinus fontinalis</i>
20. Dolly Varden trout †	-----	<i>Salvelinus malma</i>
21. Common lake trout * †	-----	<i>Salvelinus namaycush namaycush</i>

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APPENDIX A. CONVERSION TABLES

Common Water Measurements Useful to Fisheries Workers

1 acre-foot	43,560 cubic feet
1 acre-foot	325,850 gallons
1 cubic foot of water	7.48 gallons
1 cubic foot of water	62.4 pounds
1,000,000 cubic feet	22.95 acre-feet
1 gallon	231 cubic inches
1 gallon	0.1337 cubic feet
1 gallon of water	8.34 pounds
100 gallons per minute	0.223 second-feet
100 gallons per minute	0.442 acre-feet per day
1,000,000 gallons per day	1.55 second-feet
1,000,000 gallons per day	3.07 acre-feet
1,000,000 gallons per day	694 gallons per minute
1 horsepower	1 second-foot of water falling 8.8 feet
1 inch deep on 1 square mile	2,323,000 cubic feet
1 inch deep on 1 square mile	0.0735 second-feet annually
100 miner's inches *	4.96 acre-feet per day
100 miner's inches *	18.7 gallons per second
1 second-foot	1 acre-inch per hour
1 second-foot	86,400 cubic feet per day
1 second-foot	approximately 2 acre-feet per day
1 second-foot	7.48 gallons per second or 448.8 gallons per minute
1 second-foot	646,317 gallons per day
1 second-foot	40 miner's inches *

$$\frac{\text{Second-foot} \times \text{fall in feet}}{11} = \text{horsepower on waterwheel operating at 80 percent efficiency.}$$

$$\frac{\text{Acre-foot} \times 43,560}{86,400 \times X} = \text{second-foot discharge over a period X days.}$$

Discharge in second-feet

1 second-foot for 1 day	= 1.983 acre-feet; for 30 days — 59.5 acre-feet
2 second-foot for 1 day	= 3.967 acre-feet; for 30 days — 119.0 acre-feet
3 second-foot for 1 day	= 5.950 acre-feet; for 30 days — 178.5 acre-feet
4 second-foot for 1 day	= 7.934 acre-feet; for 30 days — 238.0 acre-feet
5 second-foot for 1 day	= 9.917 acre-feet; for 30 days — 297.5 acre-feet
6 second-foot for 1 day	= 11.90 acre-feet; for 30 days — 357.0 acre-feet
7 second-foot for 1 day	= 13.88 acre-feet; for 30 days — 416.0 acre-feet
8 second-foot for 1 day	= 15.87 acre-feet; for 30 days — 476.0 acre-feet
9 second-foot for 1 day	= 17.85 acre-feet; for 30 days — 535.5 acre-feet

* The second-foot (cubic foot per second = c.f.s.) is the universal unit for determining water measurements. The miner's inch is used in sections where mining activities are common. It is not standard and in California two standards are in common use. In the northern parts of the State 1 second-foot is considered to equal 40 miner's inches, while in the southern part the second-foot is considered to equal 50 miner's inches. In other western states, other values are placed on the miner's inch, so that when miner's inches are used in water measurements it is necessary to apply the standard in use in that particular area. In the above, the miner's inch (40 to 1 second-foot) is used. See California law 1901.

Common Water Measurement

Equivalents

Unit	Gallon	Quart	Pint	Pound	Avoirdupois ounce	Fluid ounce
1 gallon-----	1.0	4.0	8.0	8.345	133.52	128.0
1 quart-----	0.25	1.0	2.0	2.086	33.38	32.0
1 pint-----	0.125	0.5	1.0	1.043	16.69	16.0
1 pound-----	0.12	0.48	0.96	1.0	16.0	15.35
1 ounce-----	0.0075	0.03	0.06	0.0625	1.0	0.96
1 fluid ounce-----	0.0078	0.031	0.062	0.062	1.04	1.0
1 cubic inch-----	0.0043	0.017	0.035	0.036	0.573	0.554
1 cubic foot-----	7.481	29.922	59.848	62.428	998.848	957.48
1 cubic centimeter-----	0.0003	0.001	0.002	0.002	0.035	0.034
1 liter-----	0.264	1.057	2.1134	2.205	35.28	33.815
1 gram-----			0.002	0.0022	0.0353	0.034

Unit	Cubic inch	Cubic foot	Milliliter	Liter	Gram
1 gallon-----	231.0	0.1337	3,785.4	3.785	3,785.4
1 quart-----	57.749	0.0334	946.36	0.95	946.35
1 pint-----	28.875	0.0167	473.18	0.47	473.18
1 pound-----	27.67	0.016	453.59	0.454	453.59
1 ounce-----	1.73	0.001	28.3	0.03	28.35
1 fluid ounce-----	1.8		29.57	0.03	29.41
1 cubic inch-----	1.0	0.0006	16.39	0.0164	16.3
1 cubic foot-----	1,728.0	1.0	28,322.0	28.316	28,318.58
1 milliliter-----	0.061		1.0	0.001	1.0
1 liter-----	61.025	0.0353	1,000.0	1.0	1,000.0

Water Velocity and Flow Measurements

The measurement of water velocity and volume of flow under field conditions may be determined as follows:

Velocity

1. Locate two points 100 feet apart.*
2. Time in seconds for float to drift distance between points gives number of seconds per 100 feet.
3. Compute number of feet traveled per second.

Volume (or rate) of flow

$$\text{Formula: } R = \frac{W \text{ Da } L}{T}$$

Where R = volume of flow in cubic feet per second.

W = average width of stream in feet.

D = average depth in feet.

a = constant factor for bottom type.

Smooth sand, etc. = 0.9

Rough rocks, etc. = 0.8

L = length of stream section measured.

T = time in seconds for float to travel the measured distance.

Hydraulic Equivalents

1. Velocity of flow in a pipe in feet per second = $\frac{\text{g.p.m.} \times 0.408}{(\text{diameter in inches})^2}$
2. Doubling the diameter of a pipe increases its capacity four times.

* If it is impractical to use 100 feet as a unit for determination of velocity, any convenient distance may be used.

3. Each foot elevation of a column of water produces a pressure of about one-half pound per square inch.
4. The gallons per minute a pipe will deliver equals 0.0408 times the square of the inside diameter, multiplied by the velocity in feet per second.
5. The capacity of a pipe or cylinder in gallons equals the square of the inside diameter in inches multiplied by the length in inches and by 0.0034.
6. The discharge from any pipe in cubic feet per minute equals the square of the inside diameter multiplied by the velocity in feet per minute and by 0.00545.

Capacity of Round Tanks One Foot in Depth in U. S. Gallons *

Diameter of tank in feet	Number of gallons	Cubic feet and area in square feet	Diameter of tank in feet	Number of gallons	Cubic feet and area in square feet
1.0-----	5.87	0.785	11.0-----	710.90	95.03
1.5-----	13.22	1.767	11.5-----	776.99	103.87
2.0-----	23.50	3.142	12.0-----	845.35	113.10
2.5-----	36.72	4.909	12.5-----	918.00	122.72
3.0-----	52.88	7.069	13.0-----	992.91	132.73
3.5-----	71.97	9.621	13.5-----	1,070.80	143.14
4.0-----	94.00	12.566	14.0-----	1,151.50	153.94
4.5-----	118.97	15.90	14.5-----	1,235.30	165.13
5.0-----	146.88	19.63	15.0-----	1,321.90	176.71
5.5-----	177.72	23.76	15.5-----	1,411.50	188.69
6.0-----	211.51	28.27	16.0-----	1,504.10	201.06
6.5-----	248.23	33.18	16.5-----	1,599.50	213.82
7.0-----	287.88	38.48	17.0-----	1,697.90	226.98
7.5-----	330.48	44.18	17.5-----	1,799.30	240.53
8.0-----	376.01	50.27	18.0-----	1,903.60	254.47
8.5-----	424.48	56.75	18.5-----	2,010.20	268.80
9.0-----	475.89	63.62	19.0-----	2,120.90	283.53
9.5-----	530.24	70.88	19.5-----	2,234.00	298.65
10.0-----	587.52	78.54	20.0-----	2,350.10	314.16
10.5-----	640.74	86.59			

* To find the capacity of tanks larger than 20 feet in diameter, refer to the table for a tank of half the given size and multiply its capacity by four.

Weights (in Grams) of Chemicals Required to Produce Desired Dilutions in Known Volumes of Water *

Dilution	U. S. gallons of water					
	1	5	10	15	20	25
1:1,000-----	3.78	18.93	37.85	56.78	75.70	94.60
1:2,000-----	1.89	9.46	18.93	28.39	37.85	47.30
1:3,000-----	1.26	6.31	12.62	18.92	25.23	31.50
1:4,000-----	0.95	4.73	9.46	14.19	18.92	23.60
1:5,000-----	0.76	3.79	7.57	11.35	15.14	18.90
1:10,000-----	0.38	1.89	3.79	5.68	7.57	9.40
1:15,000-----	0.25	1.26	2.52	3.78	5.05	6.30
1:20,000-----	0.19	0.95	1.89	2.84	3.78	4.70
1:100,000-----	0.038	0.19	0.38	0.57	0.76	0.90

* The table can be used to obtain any dilution for any volume. For example, if a 1:40,000 dilution is desired in 50 gallons of water, use the figure for the 1:20,000 dilution for 25 gallons (4.70).

Concentrations

- 1.0 percent salt solution = 0.622 pounds salt (9.9 ounces) to 1 cubic foot water.
 2.5 percent salt solution = 1.5 pounds salt (24.8 ounces) to 1 cubic foot water.
 3.0 percent salt solution = 1.86 pounds salt (29.8 ounces) to 1 cubic foot water, or
 0.25 pounds salt per gallon of water.

1 p.p.m. (part per million) = 8.34 pounds per million gallons water

1 p.p.m. = 0.0584 grains per gallon

1 grain per gallon = 17.12 p.p.m.

1 grain per gallon = 142.9 pounds per million gallons

1 pound per million gallons = 0.1199 p.p.m.

Oxygen in p.p.m. $\times 0.7$ = cubic centimeters or milliliters per liter

Oxygen in cubic centimeters or milliliters per liter $\times 1.429$ = oxygen in p.p.m.

Carbon dioxide in p.p.m. $\times 0.509$ = cubic centimeters or milliliters per liter

Carbon dioxide in cubic centimeters or milliliters per liter $\times 1.964$ = carbon dioxide (CO_2) in p.p.m.

Dosage Calculations

For a 1 percent solution, add:

38 grams per gallon

1.3 ounces per gallon

10 grams per 1,000 milliliters

38 milliliters per gallon

10 milliliters per 100 milliliters (1 liter)

For other percent solutions, multiply by factors concerned. Thus, a 5 percent solution is 5×38 grams per gallon.

To prepare a 1:1,000 solution, add:

3.8 grams per gallon

1 gram per 1,000 milliliters

0.13 ounce per gallon

1 milliliter per 1,000 milliliters

For other solutions, multiply or divide by factors concerned:

1:50,000 is $1/50$ as strong as a 1:1,000 solution. Divide 3.8 grams by 50 and add this amount per gallon.

A 1:500 solution is twice as strong as 1:1,000. Multiply 3.8 grams by 2 to prepare this solution.

Feeding Drugs

To feed a 1 percent level in food, add:

5.4 grams per pound of food

0.2 ounces per pound of food

83 grains per pound of food

For other dosage levels, multiply by appropriate factor.

Example: For a 2 percent diet level, multiply 5.4 grams by 2 and add to one pound of food.

For a 0.2 percent level, multiply by 0.2.

Disinfecting Solutions

For distribution units, troughs, tanks, etc.

Active agent—Chlorine, in sodium hypochlorite

Chlorox—1 quart to 83 gallons of water

1 pint to 42 gallons of water

$\frac{1}{2}$ pint to 21 gallons of water

Hilex—1 quart to 55 gallons of water

1 pint to 27 gallons of water

$\frac{1}{2}$ pint to 13.5 gallons of water

Conversion Table, Grams per Liter to Ounces per Gallon

Grams per liter	Ounces (avoir.) per gallon (U.S.)	Percent solution	Grams per liter	Ounces (avoir.) per gallon (U.S.)	Percent solution
100.....	13.35	10	9.....	1.20	0.9
90.....	12.02	9	8.....	1.07	0.8
80.....	10.68	8	7.....	0.93	0.7
75.....	10.01	7.5	6.....	0.80	0.6
70.....	9.35	7	5.....	0.67	0.5
60.....	8.01	6	4.....	0.53	0.4
50.....	6.68	5	3.....	0.40	0.3
40.....	5.34	4	2.....	0.27	0.2
30.....	4.01	3	1.....	0.13	0.1
25.....	3.34	2.5	0.75.....	0.10	0.075
20.....	2.67	2	0.5.....	0.07	0.05
10.....	1.34	1	0.25.....	0.03	0.025

Conversion Table, Temperatures in Degrees Fahrenheit and Centigrade

Degrees C.	Degrees F.	Degrees C.	Degrees F.
0.....	32.0	52.....	125.6
2.....	35.6	54.....	129.2
4.....	39.2	56.....	132.8
6.....	42.8	58.....	136.4
8.....	46.4	60.....	140.0
10.....	50.0	62.....	143.6
12.....	53.6	64.....	147.2
14.....	57.2	66.....	150.8
16.....	60.8	68.....	154.4
18.....	64.4	70.....	158.0
20.....	68.0	72.....	161.6
22.....	71.6	74.....	165.2
24.....	75.2	76.....	168.8
26.....	78.8	78.....	172.4
28.....	82.4	80.....	176.0
30.....	86.0	82.....	179.6
32.....	89.6	84.....	183.2
34.....	93.2	86.....	186.8
36.....	96.8	88.....	190.4
38.....	100.4	90.....	194.0
40.....	104.0	92.....	197.6
42.....	107.6	94.....	201.2
44.....	111.2	96.....	204.8
46.....	114.8	98.....	208.4
48.....	118.4	100.....	212.0
50.....	122.0		

*Conversion Formulas*Degrees Centigrade = $\frac{5}{9} \times ^\circ \text{Fahrenheit} - 32$ Degrees Fahrenheit = $\frac{9}{5} \times ^\circ \text{Centigrade} + 32$

Conversion Table, Inches to Millimeters

Inches	Mm.	Inches	Mm.	Inches	Mm.	Inches	Mm.
$\frac{1}{8}$	3	$3\frac{1}{8}$	79	$6\frac{1}{8}$	156	$9\frac{1}{8}$	232
$\frac{1}{4}$	6	$3\frac{1}{4}$	83	$6\frac{1}{4}$	159	$9\frac{1}{4}$	235
$\frac{3}{8}$	10	$3\frac{3}{8}$	86	$6\frac{3}{8}$	162	$9\frac{3}{8}$	238
$\frac{1}{2}$	13	$3\frac{1}{2}$	89	$6\frac{1}{2}$	165	$9\frac{1}{2}$	241
$\frac{5}{8}$	16	$3\frac{5}{8}$	92	$6\frac{5}{8}$	168	$9\frac{5}{8}$	244
$\frac{3}{4}$	19	$3\frac{3}{4}$	95	$6\frac{3}{4}$	171	$9\frac{3}{4}$	248
$\frac{7}{8}$	22	$3\frac{7}{8}$	98	$6\frac{7}{8}$	175	$9\frac{7}{8}$	251
1	25	4	102	7	178	10	254
$1\frac{1}{8}$	29	$4\frac{1}{8}$	105	$7\frac{1}{8}$	181	$10\frac{1}{8}$	257
$1\frac{1}{4}$	32	$4\frac{1}{4}$	108	$7\frac{1}{4}$	184	$10\frac{1}{4}$	260
$1\frac{3}{8}$	35	$4\frac{3}{8}$	111	$7\frac{3}{8}$	187	$10\frac{3}{8}$	264
$1\frac{1}{2}$	38	$4\frac{1}{2}$	114	$7\frac{1}{2}$	191	$10\frac{1}{2}$	267
$1\frac{5}{8}$	41	$4\frac{5}{8}$	117	$7\frac{5}{8}$	194	$10\frac{5}{8}$	270
$1\frac{3}{4}$	44	$4\frac{3}{4}$	121	$7\frac{3}{4}$	197	$10\frac{3}{4}$	273
$1\frac{7}{8}$	48	$4\frac{7}{8}$	124	$7\frac{7}{8}$	200	$10\frac{7}{8}$	276
2	51	5	127	8	203	11	279
$2\frac{1}{8}$	54	$5\frac{1}{8}$	130	$8\frac{1}{8}$	206	$11\frac{1}{8}$	283
$2\frac{1}{4}$	57	$5\frac{1}{4}$	133	$8\frac{1}{4}$	210	$11\frac{1}{4}$	286
$2\frac{3}{8}$	60	$5\frac{3}{8}$	137	$8\frac{3}{8}$	213	$11\frac{3}{8}$	289
$2\frac{1}{2}$	64	$5\frac{1}{2}$	140	$8\frac{1}{2}$	216	$11\frac{1}{2}$	292
$2\frac{5}{8}$	67	$5\frac{5}{8}$	143	$8\frac{5}{8}$	219	$11\frac{5}{8}$	295
$2\frac{3}{4}$	70	$5\frac{3}{4}$	146	$8\frac{3}{4}$	222	$11\frac{3}{4}$	298
$2\frac{7}{8}$	73	$5\frac{7}{8}$	149	$8\frac{7}{8}$	225	$11\frac{7}{8}$	302
3	76	6	152	9	229	12	305

Conversion Table, Miscellaneous Measures and Weights

1 acre	0.404687 hectare
1 acre	43,560 square feet
1 acre	208.71 feet square
1 centimeter	0.3937 inch
1 yard	91.44 centimeters
1 meter	39.37 inches
1 inch	2.54 centimeters
1 gram	15.432 grains
1 kilogram	2,205 pounds
1 pound	7,000 grains

APPENDIX B. GLOSSARY

Abdomen

Belly; the ventral side of the fish surrounding the cavity containing the digestive and reproductive organs.

Abdominal

Pertaining to the belly; said of the pelvic fins of fishes when inserted behind the pectorals.

Acclimatization

The adaptation of fishes to a new environment or habitat or to different climatic conditions.

Adipose fin

A fleshy fin-like projection without rays, behind the rayed dorsal fin.

Agglutination

The formation of clumps or floccules by pollen, bacteria, erythrocytes, spermatozoa, and some protozoans.

Air bladder or swim bladder

A membranous sac filled with gas situated in the body cavity of fishes, ventral to the vertebral column.

Albino

Abnormal congenital deficiency of black pigmentation. Albinos have pink eyes because of lack of pigmentation.

Alevin

A young fish, especially a newly-hatched salmon or trout before absorption of the yolk sac.

Alimentary tract

The digestive tract or canal.

Ammocoete

The larval form of lampreys.

Amphibious

Capable of living both on land and in water.

Anadromous

Said of fishes which migrate from salt to fresh water to spawn.

Anal

Pertaining to the anus or vent.

Anal fin

The fin on the ventral median line behind the anus.

Anal papilla

A protuberance in front of the genital pore and behind the vent in certain groups of fishes.

Annulus

A yearly mark formed by a zone of irregularities in the sculpturing on scales, corresponding to a period of slow growth.

Anterior

In front of, or toward the head end.

Anus

The external posterior opening of the intestine; the vent.

Aquarium (pl. aquaria)

A tank or other suitable container in which fishes and other aquatic organisms may be maintained.

Artery

A blood vessel carrying blood away from the heart.

Articulate

Jointed; said of the structure of soft fin rays.

Assimilation

The transformation of digested nutriments into the fluids of an organism by a process of constructive metabolism.

Atrium

The auricular portion of the heart.

Atrophy

Nondevelopment; diminution in size.

Attenuate

Long and slender.

Auditory

Referring to the ear or to hearing.

Axilla

The region just behind or under the pectoral fin base.

Backbone

Vertebral column.

Bacterium (pl. bacteria)

One of a large, widely distributed group of typically one-celled microorganisms, often parasitic.

Bar

Vertical color mark on fishes.

Barbel

An elongated fleshy projection, usually about the head.

Barbiturate

One of a large group of drugs used as sedatives, hypnotics, etc.

Basal

Pertaining to the base; at or near the base of a fin.

Bicuspid

Having two points, split into two parts.

Blastoderm

The foundation from which the embryo will form. For practical purposes, the blastoderm is the same as the blastodisc or germinal disc.

Blastodisc

See blastoderm.

Blastopore

As the blastoderm grows over the egg it finally leaves a circular opening or blastopore.

Blastula

A hollow ball of cells, one of the early stages in embryological development.

Body

The region from the gill openings to the anus.

Bony fishes

Fishes having a hard calcified skeleton as contrasted with a cartilaginous one.

Branchiae

Gills, the respiratory organs of fishes.

Branchiocranium

The bony skeleton supporting the gill arches.

Branchiostegals

The bony rays supporting the branchiostegal membrane, under the head of fishes, below the opercular bones, behind the lower jaw, and attached to the hyoid arch.

Breast

An area with indefinite boundaries between the pelvic fins and the isthmus; sometimes called chest.

Buccal

Pertaining to the mouth.

Buccal disc

A circular funnel-like structure around the mouth in lampreys.

Buccal incubation

Incubation of eggs in the mouth; oral incubation.

Bulbus arteriosus

The blood-collecting chamber between the heart and the ventral aortae. The bulbus arteriosus is not a contracting chamber, hence is actually part of the following artery system rather than of the heart itself.

Caecal

Of the form of a blind sac.

Caecum (pl. caeca)

An appendage in the form of a blind sac, connected with the alimentary canal, such as one of the pyloric caeca at the posterior end of the stomach or pylorus.

Canine teeth

Elongated, conical teeth on the jaws, much longer than the other teeth.

Carnivorous

Eating flesh; feeding or preying on animals.

Cartilage

A substance more flexible than bone but serving the same purpose. A trout's skeleton is at first all cartilage but later part of it changes to bone.

Caseous

Cheesy.

Catadromous

Said of fishes which migrate from fresh to salt water to spawn.

Catalyst

An agent, e.g., an enzyme, which can accelerate or retard, or initiate, a reaction and apparently remains unchanged.

Caudal

Pertaining to the tail.

Caudal fin

The unpaired fin at the posterior end of the body; the tail fin of fishes.

Caudal peduncle

The tapering or slender portion of the body behind the base of the last ray of the anal fin.

Cell

A microscopic unit in the structure of the body of a fish (and other living organisms). Each cell is surrounded by a membrane and has a nucleus and other distinctive features, but in one part of the body the cells may be quite different from those in another part. For example, the cells in the skin of a fish look much different from those in the liver.

Centrum

The body of a vertebra.

Cercaria (pl. cercariae)

A heart-shaped trematode larva with a tail.

Cerebellum

A single lobe of the brain situated at the top and rear.

Cerebral hemispheres

The front lobes of the brain.

Cheek

The fleshy area behind and below the eye and anterior to the opercle.

Chin

The region at the tip of the lower jaw.

Chlorophyll

The green coloring matter found in plants and in some animals.

Chromatophores

Colored pigment cells.

Chromosomes

Units of heredity in the nucleus of cells.

Circuli

The more or less concentric growth marks in a fish scale.

Class

In classification, a division of a phylum, divided into orders.

Cloaca

The common cavity into which the rectal, urinary, and genital ducts open.

Coelomic cavity

The body cavity containing the internal organs.

Colloid

A gelatinous substance which does not readily diffuse through an animal or vegetable membrane.

Compressed

Flattened from side to side, as in the case of a sunfish.

Cornea

Outer covering of the eye.

Cranium

The part of the skull enclosing the brain.

Ctenoid scales

Scales with minute spines on their distal exposed portions. The spines can be felt by gently rubbing the fish with the finger, or they can be seen with a lens.

Cycloid scales

Scales without spines, but with concentric lines called circuli and annuli. Such scales are smooth to the touch.

Cyst

The capsule or enclosing membrane round certain cells, such as bacteria and protozoans in the resting stage.

Cytoplasm

The contents of a cell, exclusive of the nucleus.

Deciduous

Temporary, falling off easily ; said of the scales of certain fishes.

Degossypolize

To remove the toxic compound gossypol from cottonseed.

Dentary bones

The principal or anterior bones of the lower jaw or mandibles. They usually bear teeth.

Depressed

Flattened in the up and down direction.

Depth of fish

The greatest vertical diameter ; usually taken just in front of the dorsal fin.

Dermal

Pertaining to the skin.

Dermis

The skin.

Distal

The remote or extreme end of a structure.

Dorsal

Pertaining to the back.

Dorsal fin

The fin on the back or dorsal side, in front of the adipose fin if it is present.

Dorsal fin ray

One of the cartilaginous rods which support the membranes of the fin on the back of a fish.

Ductus pneumaticus

A tube that connects the air bladder with the esophagus. (Absent in black bass, sunfishes, and other spiny-rayed fishes.)

Ectoderm

The outer layer of cells which gives rise to various organs as the embryo develops.

Ectoparasite

A parasite living outside the body of a fish.

Egg

An ovum which when fertilized may develop into an animal.

Electrolyte

A substance in which the conduction of electricity is accompanied by chemical decomposition.

Emarginate fin

Fin with the margin containing a shallow notch, as in the caudal fin of the rock bass.

Embryo

A young organism in the early stages of development, before it becomes self-supporting.

Endocrine

A ductless gland.

Endoparasite

A parasite living inside a fish.

Endoskeleton

The skeleton proper; the inner bony framework.

Enzyme

A catalyst produced by living organisms and acting on one or more specific substrates.

Epidermis

The outer layer of the skin.

Esophagus

The gullet, a musculomembranous canal extending from the pharynx to the stomach.

Excretion

The process of getting rid of or throwing off waste products by any organism.

Exudation

Any discharge through an incision or pore.

Exoskeleton

The hard bony parts on the exterior surfaces, such as scales, scutes, and bony plates.

Fauna

The animals inhabiting any region, taken collectively.

Fertilization

The union of the sperm and egg.

Finfold

A ridge of tissue on the embryo which gives rise to one or more of the fins.

Fish

Any of numerous, cold-blooded, aquatic, water-breathing, craniate vertebrates having the limbs developed as fins. When used in the plural, fish refers to two or more specimens of the same species.

Fishes

The plural of fish used when referring to two or more kinds of fishes.

Flagellated

Furnished with flagella.

Flagellum

A lash-like process, as in some Protozoa and cells.

Flash

A term used to describe the quick turning movements of fish, especially when annoyed by external parasites, causing a momentary reflection of light from their sides and bellies. In flashing, fish often scrape the sides and bottom of the pond to rid themselves of the parasites.

Foramen

A hole or opening.

Fork length

The distance from the tip of the snout to the fork of the caudal fin.

Frenum

A small piece of skin binding the lip to the edge of the jaw.

Fry

The young of fishes.

Fungus

Any of a group of thallophytic plants (Fungi), lacking chlorophyll. Fungi comprise the molds, mildews, rusts, smuts, mushrooms, and others; some kinds are parasitic on fishes.

Gall bladder

The body vessel containing bile.

Gape

The opening of the mouth.

Gastrula

The embryonic stage of development consisting of two layers enclosing a sac-like central cavity with a pore at one end.

Genetics

The science of heredity and variation.

Genital

Pertaining to the region of the reproductive organs.

Genus

One of the subdivisions of the family, consisting of one or a group of closely related species.

Germinal disc

The disc-like area of an egg yolk on which segmentation first appears; blastodisc.

Gill arch

The cartilage which supports the gill filaments. The trout has four on each side of its head.

Gill bud

The embryonic stage of the future gill.

Gill clefts or slits

Spaces between the gills connecting the pharyngeal cavity with the gill chamber.

Gill cover

The flap-like cover of the gill and gill chamber; the opercle.

Gill filament

The slender, delicate, fringe-like structure composing the gill.

Gill membranes

The skin or dermal membranes, supported by the branchiostegals, more or less restricting the gill opening in the region of the isthmus.

Gill openings

The external openings of the gill chambers. A single pair is present in all true fishes found in fresh water.

Gill rakers

A series of bony appendages, variously arranged along the anterior and often the posterior edges of the gill arches.

Gills

The highly vascular, fleshy filaments used in aquatic respiration.

Globulin

One of a group of proteins insoluble in water, but soluble in dilute solutions of neutral salts.

Gonads

The reproductive organs; testes and ovaries.

Guanin

A waste product of the blood with the power of reflecting light.

Gullet

The esophagus.

Hermaphrodite

An individual that contains the reproductive or generative organs of both sexes.

Heterocercal

Said of the tail of fishes when the upper and lower lobes are not equal in length.

Holotype

The specimen on which the description of a new species is based.

Homocercal

Said of the tail of fishes when the lobes are equal in length, as in an adult trout, or when the tail is pointed.

Hormone

A substance normally produced in certain cells of the body, transported to other distant cells, and necessary for the proper functioning of the body; an internal secretion of ductless glands which passes into blood vessels by osmosis.

Hybrid

The offspring from crossing two different species.

Hyoid bones

Bones in the floor of the mouth, supporting the tongue.

Hypurals

The modified plate-like last few vertebrae supporting the caudal fin rays.

Ichthyophthirius ("Ich")

A protozoan parasite of fishes producing "white-spot disease".

Ichthyology

The science of the study of fishes.

-id (suffix)

Indicating membership in a family, thus salmonid, a member of the Salmonidae.

-idae (suffix)

The family name always ends in -idae, as in Salmonidae.

Imbricate

Overlapping, like the shingles on a roof.

Inarticulate

Not jointed.

Incisors

Teeth compressed to form a chisel-like cutting edge.

Incubation

The process of development of embryos to the hatching period.

Inferior mouth

Mouth decidedly on the under side of the head, opening downward.

Infraoral

Below the mouth. The teeth of the mouth or disc in lampreys below the oral opening.

Inner ear

The auditory organ of vertebrates.

Insertion of fin

A term applied to the point where the paired fins arise from the body.

Interbranchial septum

The membrane separating the two gill filaments on a gill arch.

International Commission on Zoological Nomenclature

A group of men who form and interpret the rules of zoological nomenclature.

Interorbital space

The space between the eyes on the dorsal side of the head. The least width of the bony interorbital space is measured unless the fleshy interorbital space is indicated.

Interspinals

Bones to which the rays of the fins are attached.

Intestine

The lower part of the alimentary canal from the pyloric end of the stomach to the anus.

Invaginate

To fold in, as when a rubber ball is pushed in at one point.

Iris

The curtain stretched across the aqueous chamber of the eye, in front of the lens, having a contractile aperture called the pupil.

Isocercal

Said of the tail of fishes when the last vertebrae progressively become smaller and smaller and end in the median line of the caudal fin, the hypural plate being nearly obsolete.

Isotonic

Of equal tension; having equal osmotic pressure.

Isthmus

The region just anterior to the breast of a fish where the gill membranes converge; the fleshy interspace between gill openings.

Kidney

One of the pair of glandular organs in the abdominal cavity which serve to excrete urine.

Lacustrine

Living in lakes.

Larva (pl. larvae)

An immature form, which must undergo change of appearance or pass through a metamorphic stage to reach the adult state.

Lateral

Pertaining to the side.

Lateral band

A horizontal pigmented band along the sides of a fish.

Lateral line

A series of sensory tubes or pores opening to the exterior, sometimes through scales or a sensory canal, along the sides of a fish.

Length

The term length may refer to the total length, fork length, or standard length (see under each item).

Lentic

Pertaining to standing water; lenitic.

Leucocyte

A white blood corpuscle.

Lingual

Pertaining to the tongue.

Littoral

Pertaining to the shore.

Liver

The glandular organ which secretes bile.

Lotic

Pertaining to running water.

Malpighian body

The functional unit of the kidney, consisting of Bowman's capsule, the glomerulus, and the uriniferous tubule.

Mandible

Lower jaw.

Maxilla or maxillary

The hindmost bone of the upper jaw.

Melanophore

A black pigment cell; large numbers of these give trout their dark color.

Membrane

A thin "skin".

Mesentery

A fold of the peritoneum that invests the intestine and supports it from the body wall.

Metamorphosis

The rapid change in anatomical structure that transforms the larva or post-larva into the adult.

Micropyle

Aperture in the egg membrane for admission of a spermatozoon.

Miliary

Of granular appearance; consisting of small and numerous grain-like parts.

Milt

The sperm of fishes.

Miracidium

The ciliated embryo or youngest stage of a trematode.

Mottled

Blotched; color spots running together.

Mucus

A viscid or slimy substance secreted by the mucous glands.

Myomere

An embryonic muscular segment which later becomes a section of the side muscle of a fish.

Myotome

Muscle segment.

Nape

Region just behind the occiput.

Necrosis

Death of tissue.

Neural arch

The dorsal arch of a vertebra for the passage of the spinal cord.

Neural canal

The cavities formed by the neural arches as a whole.

Neural spine

The uppermost spine of a vertebra.

Nomenclature

System of naming animals, plants, organs, etc.

Nostril

An opening of the nasal chamber.

Notochord

The embryonic rod around which the vertebral column forms.

Obtuse

Blunt.

Occiput

The posterior dorsal part of the head or skull.

Opercle

Gill cover.

Opercular bone

The flat, more or less triangular bone supporting the gill cover or opercle.

Opercular flap

The fleshy prolongation of the upper posterior angle of the opercle.

Operculum

Gill cover or opercle.

Optic

Referring to the eye; e.g., the optic lobes of the brain, which are connected to and control the eyes.

Orbit

The cavity of the skull containing the eye.

Order

In classification, a group of allied organisms ranking between family and class.

Osmosis

The diffusion which takes place between two fluids or solutions through a permeable or semipermeable membrane, and tending to equalize their concentrations.

Osseous

Bony.

Otic

Pertaining to the ear.

Otoliths

Two or three small bones, somewhat spherical in shape, situated in the sacculus of the inner ear of fishes.

Ovaries

The female reproductive organs which give rise to the eggs.

Oviduct

The tube which carries eggs from the ovary to the exterior.

Oviparous

Producing eggs which are fertilized, develop, and hatch after expulsion from the body.

Ovoviviparous

Producing eggs, usually with much yolk, which are fertilized internally. Little or no nourishment is furnished by the mother during development; hatching may occur before or after expulsion.

Ovum (pl. ova)

Egg.

Paired fins

The pectoral and pelvic fins.

Palate

The roof of the mouth.

Palatines

Bones just back of the vomer in the roof of the mouth, one on each side.

Papilla (pl. papillae)

A small fleshy projection.

Papillose

Covered with papillae.

Paratype

An additional specimen, other than the holotype, on which the description of a new species is based.

Parr mark

One of the vertical color bars found on salmonids and certain other fishes.

Pectoral fins

The anterior or dorsalmost paired fins in fishes, corresponding to the anterior limbs of the higher vertebrates.

Pectoral girdle

The bones supporting the pectoral fins.

Pelvic fins

Paired fins corresponding to the posterior limbs of the higher vertebrates (sometimes called ventral fins).

Pelvic girdle

The bones supporting the pelvic fins.

Perforate

Pierced through.

Peritoneum

The membrane lining the abdominal cavity.

Perivitelline

Surrounding the yolk of an egg.

Pharynx

The cavity behind and communicating with the mouth.

Photosynthesis

The formation of carbohydrates from carbon dioxide and water which takes place in the chlorophyll-containing tissues of plants exposed to light.

Phylum

A group of animals or plants constructed on a similar general plan; a primary division in classification.

Pigment

Coloring matter.

Pituitary

An endocrine gland attached to the brain.

Premaxillaries

The bones, one on each side, forming the front of the upper jaw in fishes; usually they bear teeth.

Protozoan (pl. protozoans)

A member of the phylum Protozoa, composed of minute, single-celled animals reproducing by fission; most are aquatic and some are parasites.

Protoplasm

Living cell substance.

Protractile

Capable of being drawn in or thrust forward, as the upper jaw in many fishes.

Proximal

Nearest; basal.

Pseudocyst

A residual protoplasmic mass which swells and ruptures, liberating spores.

Pterygiophore

One of the supporting bones for each ray of the dorsal and anal fins.

Pupil of eye

The blackish central part of the eye surrounded by the iris.

Purulent

Of or consisting of pus.

Pyloric caeca

See caecum.

Radii of scale

Lines on the proximal part of a scale, radiating from near center to base.

Ray

A supporting rod for a fin. There are two kinds: hard (spines) and soft rays.

Red gland

A gland composed of a large group of capillaries situated on the air bladder.

Reticulate

Marked with a network of lines.

Roe

The eggs of fishes.

Rostrum

The snout.

Rudimentary

Undeveloped or nearly so.

Sacculus

A small sac of the internal ear.

Salinometer

An instrument for measuring the amount of salt in a solution.

Scale formula

A conventional formula used in identifying fishes. "Scales 7 + 65 + 12", for example, indicates 7 scales above the lateral line, 65 in the lateral line, and 12 below it.

Scales above the lateral line

The number of scales is counted in various ways, depending on the kind of fish. Usually the count is made in an oblique row beginning with the first scale above the lateral line and running anteriorly to the base of the dorsal fin.

Scales below the lateral line

The number of scales is counted in a row beginning at the origin of the anal fin and running obliquely dorsally either forward or backward, to the lateral line. In certain fishes this count is made from the base of the pelvic fin.

Scales in the lateral line

Usually the number of scales bearing tubes in the lateral line is counted, or the number of oblique rows crossing the lateral line is counted just above it. The first scale counted is the one at the upper edge of the opercular opening; the last one counted is at the end of the hypural plate or base of the caudal fin rays. Scales on the caudal fin base and caudal fin, even though they possess tubes, are not included in the count.

Scaly appendage

An accessory scale or fleshy triangular projection at the dorsal edge of the pelvic base on certain fishes.

Seasoned water

Water which has been conditioned for aquarium fishes. Raw tap water may be conditioned by storage for seven days in a shallow, nonmetallic pan. Artificial aeration may hasten this aging.

Second dorsal

The posterior of two fins, usually the soft-rayed dorsal fin of spiny-rayed fishes.

Septum (pl. septa)

A thin partition.

Serous

Watery; like serum.

Serum

The watery portion of an animal fluid remaining after coagulation.

Sessile

Permanently attached.

Snout

The portion of the head in front of the eyes. The snout is measured from its most anterior tip to the anterior margin of the orbit.

Soft dorsal

The part of the dorsal fin, sometimes all of it, composed of soft or articulated rays.

Soft fins

Fins with soft rays only, designated as soft dorsal, etc.

Soft rays

Fin rays that are cross-striated or articulated, like a bamboo fish pole.

Somite

A segment of the embryo's body which will later form one of the side muscles. A somite is an early stage in the formation of a myomere.

Species

A group of interbreeding individuals not ordinarily interbreeding with another such group; a systematic unit including geographic races and varieties, and included in a genus.

Spermatozoon

A male reproductive cell, consisting usually of head, middle piece, and locomotory flagellum.

Spinal cord

The cylindrical structure within the spinal canal, a part of the central nervous system.

Spines

Unsegmented rays, commonly hard and pointed.

Spinous dorsal

Anterior part of the dorsal fin of spiny-rayed fishes; any dorsal fin composed of inarticulated rays.

Spiny rays

Pungent or non-cross-striated fin rays.

Spleen

The organ in which lymphocytes are produced and red blood corpuscles destroyed, in vertebrates.

Standard length

The distance from the tip of the snout to the base of the caudal fin rays.

Superior

As applied to the mouth, the term means opening in a more dorsal or upward as opposed to anteriorly facing or ventral direction.

Syndrome

A group of concomitant symptoms.

Synonymy

A list of the scientific names which have been applied to the same species or other group, other than the valid name.

Tactile

Pertaining to the sense of touch.

Tail

The part of the body behind the body cavity.

Terminal mouth

The mouth is so designated when situated in the horizontal axis of the head, with neither chin nor snout projecting.

Testes

The male reproductive organs which give rise to sperm.

Titration

A method, or the process, of determining the strength of a solution, or the concentration of a substance in solution, in terms of the smallest amount of it required to bring about a given effect in reaction with another known solution or substance.

Total length

The distance from the tip of the snout to the tip of the caudal fin.

Transverse

Crosswise.

Trematode

Any of a class (Trematoda) of flatworms including the flukes and related organisms.

Truncate

Abrupt, as if cut off squarely.

Type

See holotype and paratype.

Type locality

The locality or localities from which the holotype and paratypes were collected.

Urinary bladder

The bladder attached caudally to the kidneys; the kidneys drain into it.

Urostyle

The rudimentary or embryonic rear tip of the vertebral column which occurs on the dorsal edge of the hypural plate.

Vas deferentia

The ducts by which sperm is conveyed to the seminal vesicles.

Vein

A tubular vessel that carries blood to the heart.

Vent

The external posterior opening of the alimentary canal; the anus.

Ventral aortae

Large paired arteries which carry blood from the bulbus arteriosus to the gills.

Ventral fins

Pelvic fins.

Vertebrae

The bones of the spinal column.

Vertebral column

The backbone or spinal column, composed of a series of vertebrae.

Vertical fins

Fins along the median line of the body: the dorsal, anal, and caudal fins.

Vesicle

A pouch or sac. For example, an optic vesicle in an embryonic eye.

Vestigial

Rudimentary.

Villiform

Said of the teeth of fishes when slender and crowded into velvety bands or compact patches.

Viscous

Slimy.

Vitelline membrane

The outer membrane of an egg.

Viviparous

Bringing forth living young; the mother contributes food toward the development of the embryos.

Vomer

Bone of the anterior part of the roof of the mouth, commonly triangular and often with teeth.

Xanthophore

A yellow chromatophore.

Yolk

The food part of an egg.

Zoogeography

The science of the geographical distribution of animals.

